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CHARLES F. MARVIN, Chief

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NOTICE TO CONTRIBUTORS.

Contributions intended for publication in any given issue of the MONTHLY WEATHER REVIEW (e. g., January) should be in the hands of the editor before the end of the next following month (e. g., February), if no illustrations are required. When the paper is illustrated, the manuscript and the copy for illustrations must be submitted much earlier, in order to permit copy being prepared for the engraver by the end of the month.

REPRINTS are made up without covers in the original size and pagination of the REVIEW. They will not be furnished unless specifically REQUESTED WHEN THE MANUSCRIPT IS SUBMITTED.

MONTHLY WEATHER REVIEW

CLEVELAND ABBE, jr., Editor.

VOL. 45, No. 12. DECEMBER, 1917. CLOSED FEB. 4, 1918
W. B. No. 634. ISSUED MAR. 4, 1918

INTRODUCTION.

As explained in this Introduction during 1914, the MONTHLY WEATHER REVIEW now takes the place of the Bulletin of the Mount Weather Observatory and of the voluminous publication of the climatological service of the Weather Bureau. The MONTHLY WEATHER REVIEW contains contributions from the research staff of the Weather Bureau and also special contributions of a general character in any branch of meteorology and climatology.

SUPPLEMENTS to the MONTHLY WEATHER REVIEW are published from time to time.

The climatological service of the Weather Bureau is maintained in all its essential features, but its publications, so far as they relate to purely local conditions, are incorporated in the monthly reports "Climatological Data" for the respective States, Territories, and colonies.

Beginning August, 1915, the material for the MONTHLY WEATHER REVIEW has been prepared and classified in accordance with the following sections:

SECTION 1.—*Aerology.*—Data and discussions relative to the free atmosphere.

SECTION 2.—*General meteorology.*—Special contributions by any competent student bearing on any branch of meteorology and climatology, theoretical or otherwise.

SECTION 3.—*Forecasts and general conditions of the atmosphere.*

SECTION 4.—*Rivers and floods.*

SECTION 5.—*Seismology.*—Results of observations by Weather Bureau observers and others as reported to the Washington office.

SECTION 6.—*Bibliography.*—Recent additions to the Weather Bureau library; recent papers bearing on meteorology.

SECTION 7.—*Weather of the month.*—Summary of local weather conditions; climatological data from regular Weather Bureau stations; tables of accumulated and excessive precipitation; data furnished by the Canadian Meteorological Service; monthly charts Nos. 1, 2, 3, 4, 5, 6, 7, 8, the same as hitherto; Meteorological Summary and chart No. 9 of the North Atlantic Ocean for this month in 1916. Owing to the fact that ocean meteorological data are frequently not available for a considerable time after the close of the month to which they relate, the chart and text matter in connection therewith appear one year late.

In general, appropriate officials prepare the seven sections above enumerated; but *all students of atmospherics are cordially invited to contribute such additional articles as seem to be of value.*

The voluminous tables of data and text relative to local climatological conditions, that during recent years were prepared by the 12 respective "district editors," are omitted from the MONTHLY WEATHER REVIEW, but are collected and published by States at selected section centers. (See cover, p. 3.)

The data needed in Section 7 can only be collected and prepared several weeks after the close of the month designated on the title-page; hence the REVIEW as a whole can only issue from the press within about eight weeks from the end of that month.

It is hoped that the meteorological data hitherto contributed by numerous independent services will continue as in the past. Our thanks are specially due to the directors and superintendents of the following:

The Meteorological Service of the Dominion of Canada.
The Meteorological Service of Cuba.
The Meteorological Observatory of Belén College, Habana.
The Government Meteorological Office of Jamaica.
The Meteorological Service of the Azores.
The Meteorological Office, London.
The Danish Meteorological Institute.
The Physical Central Observatory, Petrograd.
The Philippine Weather Bureau.

The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, but such publication is not to be construed as official approval of the views expressed.

CORRIGENDA.

REVIEW, November, 1917:
Page 535, col. 2, in the first equation, *for* (2213.65) *read* $(2213.65)^1/_2$.
554, col. 2, *for* Panama Canal Zone *read* Panama Canal.
554, col. 2, *for* Isthmian Canal Commission *read* Governor, Panama Canal.

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SECTION I.—AEROLOGY.

SOLAR AND SKY RADIATION MEASUREMENTS DURING DECEMBER, 1917.

By HERBERT H. KIMBALL, Professor of Meteorology.

[Dated: Washington, D. C., January 28, 1918.]

For a description of instrumental exposures and an account of the methods of obtaining and reducing the measurements the reader is referred to the REVIEW for January, 1917, **45**: 2.

The monthly means and departures from normal values given in Table 1 show that direct solar radiation averaged above normal intensity for the month at Washington and Madison, and slightly below at Lincoln and Santa Fe. At Madison an intensity of 1.49 calories, measured at noon of the 29th, slightly exceeds the highest previous December noon intensity at that station.

Table 3 shows only a slight departure from the normal radiation for the month at Madison and a deficiency of about 8 per cent at Washington.

For the year Madison shows an unimportant excess of 0.2 per cent, while Washington shows a deficiency of 5.6 per cent.

Skylight polarization measurements at Washington, on only two days when the ground was free from snow, give a mean of 51 per cent, with a maximum of 52 per cent on the 10th. At Madison observations on three days, with practically no snow on the ground, give a mean of 71 per cent with a maximum of 73 per cent on the 25th.

Corrections for Lincoln, Nebr.

As noted in the REVIEW for May, 1917, the instrumental constant for the Callendar recording pyrheliometer at Lincoln, Nebr., underwent a change commencing with August, 1916, due to improper treatment of the bridge wire on the register. Frequent comparisons are made between the Callendar and Marvin pyrheliometers by the method described and illustrated in the REVIEW for August, 1914, **42**: 477.

The Marvin pyrheliometer was standardized by comparison with Smithsonian silver block pyrheliometer "S. I., No. 1," in July, 1915. It was recompared with "S. I. No. 1," in October, 1917. On this latter occasion it read 5 per cent higher than when standardized in 1915. The instrument is of the spiral ribbon type, and it seems probable that the low readings of summer as compared with winter may be due to impaired insulation between the successive layers of the nickel ribbon of which the resistance coil is made up, during the warm and comparatively moist weather of summer.

Besides comparisons with "S. I. No. 1," the extrapolation of measurements with the Marvin pyrheliometer at Lincoln to zero air mass and the comparison of the results with a like treatment of measurements at other stations, indicates that the Lincoln measurements were too high from December, 1916, to April, 1917, by at least 5 per cent, and they have been diminished by this amount before including them in computations of the monthly normals.

When thus corrected, the comparisons between Marvin and Callendar pyrheliometers give the following corrections to be applied to records, by the latter, of the total solar and sky radiation for Lincoln, as published in this REVIEW:

MONTH.	CORRECTION.
1916.	*Per Cent.*
August	+ 2
September	+ 3
October	+ 5
November	+ 8
December	+ 8
1917.	
January	+ 8
February	+12
March	+16
April	+20

The above corrections will be applied to the daily totals for the months indicated, as published in this REVIEW, before employing the latter in the computation of daily normals and departures from normal (see Table 3) for 1918.

TABLE 1.—*Solar radiation intensities during December, 1917.*

[Gram-calories per minute per square centimeter of normal surface.]

Washington, D. C.

Date.	Sun's zenith distance.									
	0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass.									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Dec. 9			1.43							
10			1.36	1.26	1.15	1.06	0.98	0.93	0.87	
11			1.32	1.29	1.22	1.14	1.07	1.04	0.99	0.95
26				1.32	1.25					
30			1.46							
Monthly means			1.39	1.29	1.21	(1.10)	(1.02)	(0.98)	(0.93)	(0.95)
Departure from 10-year normal			+0.16	+0.15	+0.15	+0.12	+0.13	+0.16	+0.18	+0.32
P. M.										
Dec. 10					1.19	1.07				
15				0.98	0.89	0.85			0.63	
30				1.38	1.30	1.23	1.10	1.07	1.01	0.97
Monthly means				(1.18)	1.13	1.05	(1.10)	(1.07)	(0.82)	(0.97)
Departure from 10-year normal				+0.04	+0.08	+0.10	+0.21	+0.21	+0.03	+0.22

Madison, Wis.

A. M.										
Dec. 6				1.42						
21				1.42						
22					1.02	0.96	0.89	0.82	0.76	
25				1.44						
29				1 49	1.41	1.36	1.29	1.23		
Monthly means				1.44	(1.22)	(1.16)	(1.09)	(1.02)	(0.76)	
Departure from 8-year normal				+0.15	+0.01	+0.01	−0.05	−0.03	−0.16	
P. M.										
Dec. 14					1.42	1.34	1.28	1.21		
21					1.36	1.32	1.27	1.18		
29					1.44	1.38	1.25			
Monthly means					1.41	1.35	1.27	(1.20)		
Departure from 8-year normal					+0.11	+0.16	+0.15	+0.08		

TABLE 1.—*Solar radiation intensities during December, 1917*—Continued.

[Gram-calories per minute per square centimeter of normal surface.]

Lincoln, Nebr.

Date.	Sun's zenith distance.									
	0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass.									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
Dec. 8				1.42	1.38	1.23				
11				1.26	1.21	1.12	1.02			
16				1.30	1.19					
20				1.20	1.15	1.07	0.99	0.93	0.86	0.80
27				1.08		0.81				
Monthly means				1.25	1.23	1.06	(1.00)	(0.93)	(0.86)	(0.80)
Departure from 3-year normal				−0.04	−0.01	−0.06	−0.01	−0.03	±0.00	
P. M.										
Dec. 8					1.24	1.20	1.15			
18				1.15	1.10	1.06				
27					0.98	0.95	0.92	0.89	0.85	
Monthly means				(1.15)	1.11	1.07	(1.04)	(0.89)	(0.85)	
Departure from 3-year normal				−0.12	−0.08	−0.06	−0.05	−0.16	−0.13	

Santa Fe, N. Mex.

A. M.										
Dec. 7					1.39					
20				1.47	1.36	1.32	1.27	1.22		
27				1.46	1.38	1.30				
28				1.46	1.39	1.33	1.26	1.20	1.18	1.15
29					1.34	1.28	1.22	1.17	1.11	
Monthly means				1.46	1.37	1.31	1.25	1.20	(1.14)	(1.15)
Departure from 6-year normal				−0.04	−0.05	−0.05	−0.05	−0.04	−0.03	−0.01
P. M.										
Dec. 3				1.43	1.36	1.30	1.23	1.18	1.14	1.08
6				1.46		1.20	1.21			0.99
19				1.50			1.26	1.25	1.17	1.10
27					1.36	1.31	1.24	1.17	1.10	
28				1.47	1.38	1.28	1.26	1.18	1.11	1.04
31								1.22	1.15	
Monthly means				1.46	1.37	1.27	1.24	1.20	1.13	1.05
Departure from 2-year normal				−0.22	−0.03	−0.01				

TABLE 2.—*Vapor pressures at pyrheliometric stations on days when solar radiation intensities were measured.*

Washington, D. C.			Madison, Wis.			Lincoln, Nebr.			S anta Fe, N. Mex.		
Dates.	8 a.m.	8 p.m.	Dates.	8 a.m.	8 p.m.	Dates.	8 a.m.	8 p.m.	Dates.	8 a.m.	8 p.m.
1917.	mm.	mm.	1917.	mm.	mm.	1917.	mm.	mm.	1917.	mm.	mm.
Dec. 9	0.74	1.07	Dec. 6	1.19	1.32	Dec. 8	0.41	0.74	Dec. 3	3.45	2.62
10	0.71	1.19	14	0.97	0.81	11	0.71	1.88	6	1.45	2.49
11	0.97	1.32	21	3.15	2.06	16	1.78	3.99	7	2.16	2.49
15	1.19	1.32	22	2.11	4.37	18	3.81	4.57	19	2.62	3.63
26	1.45	1.96	25	0.48	0.86	20	4.57	4.37	20	2.16	3.00
30	0.53	0.71	29	0.41	0.66	27	2.26	0.71	27	3.45	3.15
									28	3.15	2.87
									29	2.36	2.87
									31	2.26	3.15

TABLE 3.—*Daily totals and departures of solar and sky radiation during December, 1917.*

[Gram-calories per square centimeter of horizontal surface.]

Day of month.	Daily totals.		Departures from normal.		Excess or deficiency since first of month.	
	Washington.	Madison.	Washington.	Madison.	Washington.	Madison.
1917.	calories.	calories.	calories.	calories.	calories.	calories.
Dec. 1	152	176	−28	43	−28	43
2	248	58	70	−74	42	−31
3	70	166	−106	35	−64	4
4	24	93	−150	−37	−214	−33
5	190	105	18	−25	−196	−58
6	137	229	−33	99	−229	41
7	74	166	−95	36	−324	77
8	15	209	−152	79	−476	156
9	288	199	123	69	−353	225
10	272	219	108	89	−245	314
Dec. 11	227	200	65	69	−180	383
12	167	99	6	−32	−174	351
13	60	209	−100	78	−274	429
14	71	212	−89	80	−363	509
15	221	160	62	28	−301	537
16	115	132	−44	−1	−345	536
17	130	171	−29	38	−374	574
18	92	35	−67	−99	−441	475
19	66	34	−93	−100	−534	375
20	184	26	25	−109	−509	266
Decade departure.					−264	−48
Dec. 21	197	191	38	56	−471	323
22	208	112	48	−24	−423	298
23	207	20	47	−116	−376	182
24	109	86	−51	−51	−427	131
25	20	198	−140	61	−567	192
26	218	121	58	−17	−509	175
27	171	41	10	−98	−499	77
28	168	98	7	−42	−492	35
29	122	211	−39	70	−531	105
30	268	59	107	−83	−424	22
31	190	161	28	18	−396	40
Decade departure.					+113	−226
Excess or deficiency since first of year	cal				−7,164	+187
	per cent				−5.6	+0.2

LUNAR TOTAL ECLIPSE, 1917, JULY 4.[1]

By L. PICARD.

[*Reprinted from* Science Abstracts, Sect. A, Dec. 31, 1917, § 1347.]

Observations by three persons during the lunar eclipse of 1917, July 4, at the Bordeaux-Floriac observatory, indicated that the edges of the moon's limb appeared much brighter than the central portions. Also that the northern limb appeared much brighter than the southern, the moon passing to the north of the axis of the shadow cone; and that the western limb was most luminous until the middle of the eclipse, and the eastern limb during the second half of the eclipse. These facts indicate that the phenomenon is due to the solar rays being refracted on passage through the terrestrial atmosphere.—*C. P. B[uller]*.

LUNAR TOTAL ECLIPSE OF DECEMBER 27–28, 1917, AT HONOLULU.

By C. A. REICHELT, Assistant Observer.

[Dated: Weather Bureau Office, Honolulu, Hawaii, Dec. 30, 1917.]

A total eclipse of the moon, remarkable for the brightness of the moon during the eclipse period and also for the attending coronæ visible, was observed at Honolulu, Hawaii, on the night of December 27, 1917.

The eclipse as seen by the naked eye began at about 9:35 p. m. (157° 31′ meridian time), was total from 11:10

[1] Comptes rendus, Paris, Aug. 13, 1917, 165:264.

p. m. to 11:25 p. m., and ended at about 1 a. m. of December 28, 1917. Throughout the entire evening the moonlight was very bright, clouds obscuring the moon but for short intervals up to midnight after which the sky became quickly covered with heavy rainclouds and the eclipse was practically hidden. Distinct shadows of objects on the earth were still cast by the moon's light at 10:15 p. m., an hour when more than half of the moon was eclipsed and very dark, so that the moon's edge within the shadow was hardly discernible. As the eclipse progressed the darkened part became much lighter, turning to dull red and later to light red and orange. During the total phase that portion eclipsed first appeared a light red, the central portion a bright orange and the opposite edge or that eclipsed last, a very light yellow. The dark and light spots and the familiar markings on the moon's surface were almost as easily distinguishable during totality as under ordinary conditions.

Phenomena of perhaps rarer occurrence than the moon's eclipse were the lunar coronæ that were present during the earlier stages, and which were so brightly colored that they were mistaken by many people for lunar rainbows. Caused by the thinner portions of the swiftly moving Cu. and St.-Cu. clouds that passed over the moon, they appeared and vanished at irregular intervals during the evening. A few A.-Cu. clouds were also present and the humidity was very high, being above 80 per cent the entire night. The first of these coronæ was observed at 8:30 p. m., and was of about 3° or 4° radius. The circle was complete and the bands of prismatic colors very distinct. Several broken and indistinct coronæ appeared up to 9:35 p. m., when another complete ring of colors formed around the moon, this one being somewhat larger, of 4° or 5° radius, and the brightest corona of the evening. At this time the eclipse had just started and as it progressed the coronæ continued, varying in size and brightness, until at 10:00 p. m., when the moon was fully half eclipsed, a large double corona was formed and remained visible for about five minutes. It was composed of two complete concentric coronæ, the inner one being of 2° or 3° radius with very bright and distinct colored bands, the outer one of about 7° or 8° radius with its separate colors more or less blended but still easily distinguishable.

A few broken coronæ were seen after this and the final colored one was observed at 10:35 p. m., at which time the moon was about three-fourths covered by the earth's shadow. This was a small circle of 2° or 3° radius, the colors faint and the upper part broken, due to the shape of the cloud forming it. During the total phase of the eclipse no colored coronæ were visible, but as thin clouds passed between the moon and the earth a small ring of whitish light 1° or 1½° radius surrounded the darkened moon. During the final stages of the eclipse heavy clouds covered the sky, no coronæ were visible and the moon itself appeared only for very brief intervals of time.

PERMANENT PERIODICITY OF SUNSPOTS.[1]

By J. LARMOR & N. YAMAGA.

[*Reprinted from* Science Abstracts, Sect. A, Dec. 31, 1917, § 1344.]

A reëxamination of the available sunspot records for the 160 years, 1750–1910, leads to the conclusion that an unbroken solar periodicity of about 11.125 years is firmly established, if the two strongly discrepant cycles from 1776 to 1798 are left out of consideration. The graph of this periodic constituent is shown to have the property of being antisymmetrical with respect to the axis which bisects its undulations, each undulation giving equal areas above and below, the curve repeating as a reflected image. *Examination of the residuals after extraction of the 11.125-year pulses shows no indication of periods other than are sporadic in character.*

A letter is appended from Wolfer, of Zurich, giving interesting particulars concerning the compilation of the sunspot data, those of the discrepant period from 1775 to 1795 being almost exclusively made by Stoudacher of Nuremberg. The epochs of maxima, 1778 and 1787, are considered fairly reliable; and the large departures of the lengths of the periods observed between 1770 and 1805 from the mean value of 11.125 years, are to be considered as real.—*C. P. B[utler]*.

[1]Proc. Roy. soc., London, Sept. 1, 1917, 93: 493–506.

POLARIZATION OF SKYLIGHT.[1]

By A. GOCKEL.

[*Abstract of paper* presented to Swiss Society of Geophysics, etc., Zurich, Sept. 11, 1917.]

The present study was undertaken for the purpose of verifying the conjecture, made elsewhere, that there exists (1) a relation between the polarization of the skylight and the sun's activity, and (2) also a relation between this polarization and certain electric phenomena such as the propagation of hertzian waves and the rapid variations in the atmospheric electric gradient. It was first necessary to determine to what extent one might deduce daily means from isolated observations, and also whether one might use observations made on days when the sky was not perfectly free from clouds.

The Martens polariphotometer was the instrument used.

The greater portion of the observations were made on the zenith and at 90° from the sun. Further observations were made on the variation in polarization of certain points in the sky with varying distances of the sun. The time of day was found to influence the polarization independently of the location of the point observed; and it also appeared that at the same time of day and at equal distances from the sun the polarization varied with the zenithal distance of the point observed.

The variations affecting polarization at sunrise and at sunset may be explained by modifications in the sun's illumination due to the formation or shifting of haze or fogs which provoke variations in the electric gradient.

Measurements at Silvaplana (altitude = 1,800 m.) have not revealed any influence of altitude.

The formation of clouds is betrayed several hours in advance [of their appearance] by a decrease in the polarization. Cirrus and strato-cumulus scarcely lower the polarization of the blue sky areas near them, but cumulus and cumulo-nimbus affect it thus very strongly. However, one can not employ the degree of polarization of skylight for forecasting weather without taking account of all the other determining factors.

[1]*A. Gockel* (Fribourg). Polarisation de la lumière du ciel. Archives des sci. phys. et nat., Genève, 15 Nov., 1917, 44: 349.

SOLAR CORONAE: FIVE YEARS' RECENT OBSERVATIONS.[2]

By J. MAURER.

[*Abstract of paper* presented to Swiss Society of Geophysics, etc., Zurich, Sept. 11, 1917.]

Simple examination of the sky during the day almost always shows us the sun surrounded by a circular whitish luminosity whose diameter and intensity is subject to great variations. Disregarding all theoretical considerations concerning this phenomenon, it may be stated that it has not received systematic attention until quite recently, and strictly speaking only since the great atmospheric-optical disturbance of 1912. The writer has been able to interest Dr. Friederich Schmidt, our distinguished observer of the zodiacal light, and also Prof. Dorno, of Davos, who has already published quite a series of observations.[3]

Searching and continuous study of the solar nimbus shows that one often has to do with a true corona and that it is the simplest and surest criterion of the degree of purity of our atmosphere.

The first result of our observations since 1912–13 was the great solar nimbus showing two distinct minima in its diameter annually, viz, at April–May and at August–September 1; the nimbus may completely disappear at those epochs. The year 1916 has shown a quite different course from spring to fall. The spring minimum has been very slightly marked and as early as April the solar corona attained a diameter of 100°. Then in July and in August, 1916, even in the blue sky, the nimbus often assumed enormous dimensions and approached 140° toward the middle and end of August, 1916. These were the forerunners of an atmospheric-optical disturbance which other signs had revealed as early as the beginning of April.

The solar nimbus presents very remarkable phases at the epochs of great solar activity; when its diameter is 70° to 80° or even 100°, it is surrounded by a broad border distinctly colored by a tint between red and yellow-brown. The nimbus then gives absolutely the impression of a Bishop's Ring, having a notably large diameter. The intense developments of this border are accompanied, without exception, by notable telluric and atmospheric phenomena (polar auroræ, earth currents). Without doubt we then (notably June 16, 21–23, 1916, and February 11, 1917) have to do with extensive emission of cathode rays by the sun, according to Birkeland's views. The rapid appearances and disappearances of the colored ring are incompatible with the idea of an intermittent corona (auréole) due to clouds of discrete volcanic ash.

To explain the solar nimbus by the theory of diffraction requires the existence of very small particles very close together in the atmosphere; these particles would be produced by the nuclei of condensation sent to the earth by the sun during its paroxysms and which also call forth the polar auroræ.

According to Dorno there was, at Davos, an intimate and regular relation between the solar activity and the occurrence and intensity of the great solar corona. Does this relation always obtain? Prolonged observations at very diverse localities at considerable altitudes, will decide this.

[2] *J. Maurer* (Zurich). Couronnes solaires. Résultats de cinq années d'observations récentes. Arch. des sci. phys. et nat., Genève, 15 Nov. 1917, **44**: 349–350.

[3] See Astronomische Nachrichten, No. 4899, Aug. 1917, **205**; translated in this REVIEW October, 1917, **45**: 483–484. *Also*, Veröffentl. d. königl. Preuss. meteorolog. Instit., No. 295, Berlin, 1917.

NEED OF GEOPHYSICAL OBSERVING STATIONS.[5]

By P. GRUNER.

[*Abstract of* a paper presented to Swiss Society of Geophysics, etc., Zurich, Sept. 11, 1917.]

The speaker pointed out the fine recent development in the study of phenomena in atmospheric optics and electricity. Such observations of a geo- and aërophysical nature may not be asked of existing meteorological stations which are already overloaded; we need special observational posts located at favorable points (free from dust and smoke, having extended horizon) distributed throughout Switzerland *at widely differing altitudes*, and served by well-trained personnel. Concomitant observations carefully made and at diverse stations are essential for the solution of the interesting problems in atmospheric electricity, in polarization and the intensity of the skylight, of twilight (particularly the purple light) as well as their relations to meteorological, atmospheric, and astrophysical conditions.

Beside three or four principal stations after the model of the one at Davos conducted by Dr. Dorno, there should be established a series of other temporary stations (for about a semester) where young investigators could work and which would require but a small amount of material. Further, one should pay for the services of local observers here and there, in order that they devote the necessary time to such researches.

A fund for scientific research, administered by the Société Helvétique des Sciences Naturelles, would render splendid service along this line

[5] *P. Gruner*. De la nécessité d'ériger des stations d'observations géophysiques. Arch. des sci. phys. et nat., Genève, 15. Nov. 1917, **44**: 366.

SECTION II.—GENERAL METEOROLOGY.

WEST INDIES HURRICANES AS OBSERVED IN JAMAICA.

By MAXWELL HALL, M.A., F.R.A.S., F.R.Met.Soc., Barrister at Law, Government Meteorologist.

[Dated: Montego Bay, Jamaica, W. I., Dec. 3, 1917.]

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INTRODUCTION.

If we look at a chart of the West Indies it is evident that the chain of small islands which form the eastern boundary of the Caribbean Sea can give warning westward of these storms which, generating to the east of those islands, pass westward over them; but that the islands themselves will always have to depend chiefly on their own local observations.

Again, the larger islands from Porto Rico to Cuba should be continually on the watch for the possible curving northward of any storm which may be passing along the Caribbean Sea; and this applies more particularly to Jamaica; such a storm advancing from the Windward Islands may affect Jamaica in several ways, or by passing far north or far south it may hardly affect that island at all.

It thus appears that there is need for local observations to supplement the telegraphic warnings issued by the United States Weather Bureau at Washington, and it was with this object that the following pages were written.

Again, the local telegraph wires soon go down as the storm advances, hence it is advisable to consider the observer as isolated with regard to information from a distance, whether or not he has received the general warning from Washington.

Technicalities can not be avoided, but I have done my best to make the matter as simple as possible, so that any one who has a good barometer and a fair knowledge of clouds may be able to forecast for his immediate locality, and to make valuable observations for the future development of the cyclonic theory. And I may as well begin by quoting from the notice published in Jamaica at the commencement of each hurricane season:

> A barometric "depression" over a large area involves weather "disturbance"; the low barometer is always accompanied by rain, sometimes by very heavy rain; and if the depression does not speedily fill up and disappear, the wind begins to circulate about its center in a direction contrary to that of the hands of a watch face upward on a table.
>
> When this action is continued the barometer gradually falls at the center, the wind sweeps faster round the center, and the system thus established is called a "cyclone". It is to the position and motion of the centers of these "depressions" and "cyclones" that the telegraphic storm warnings refer.
>
> When a cyclone is fully developed, the wind near the calm center moves round it with "hurricane" force; so that when it is reported that a "hurricane" swept a certain island, we know that the center of a great cyclone passed over or near that island.

And with this understanding we shall continue to use the word "hurricane", which history has made applicable to a great storm in the West Indies in the same way that the word "typhoon" is applicable to a similar storm of the China seas.

GENERAL DESCRIPTION OF CYCLONES.

In the year 1886 the late Hon. Ralph Abercromby visited the observatories at Mauritius, Madras, Calcutta, Manila, Hongkong, and Tokyo, to collect information respecting tropical cyclones, and he published the results in an article "On the relation between tropical and extra-tropical cyclones."[1] It was read before the Royal Society in February, 1887, but the pamphlet he sent me contains additions up to June of that year where reference is made to the work of the late Padre Viñes at Habana. The conclusions at which he arrived are so clearly expressed and unbiased, that I can not do better than quote them in paragraphs, adding notes taken for the most part from my own observations made in Jamaica during the past 40 years.

(1) *All cyclones have a tendency to assume an oval form; the larger diameter may be in any direction, but has a decided tendency to range itself nearly in a line with the direction of propagation.*

The center of the cyclone is almost invariably toward one or other end of the longer diameter; but the displacement may vary during the course of the same depression (op. cit., p. 28).

The "oval form" is of course that of the isobars or lines of equal barometric pressure surrounding the center; but the cyclones passing over or near Jamaica in recent years have been so nearly circular that in the case of an advancing storm we can assume that the isobars are fairly circular, and lay off the direction of the center by the direction of the wind and cloud-drift in accordance with the results given in sections (11) and (13).

[1] Proceedings of the Royal Society, London, Nov. 1887, vol. 43, pp. 1—30.

FIG. 1.—Kempshot Observatory, Jamaica, B. W. I., altitude, 1,773 feet above sea-level; with commanding view in all directions.

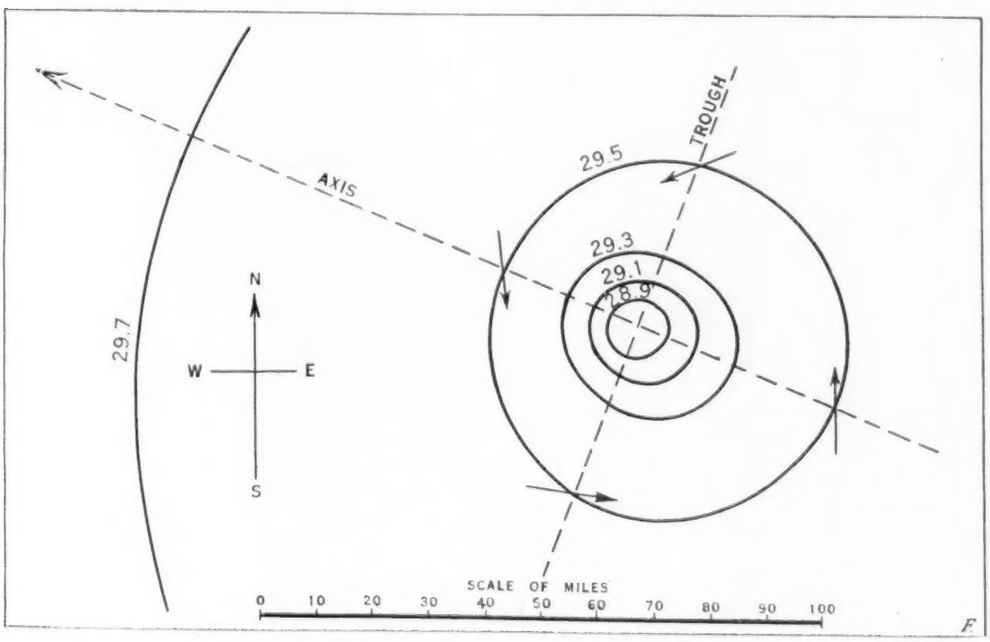

FIG. 2.—Distribution of pressure and close-in winds in an average hurricane moving west-northwestward.

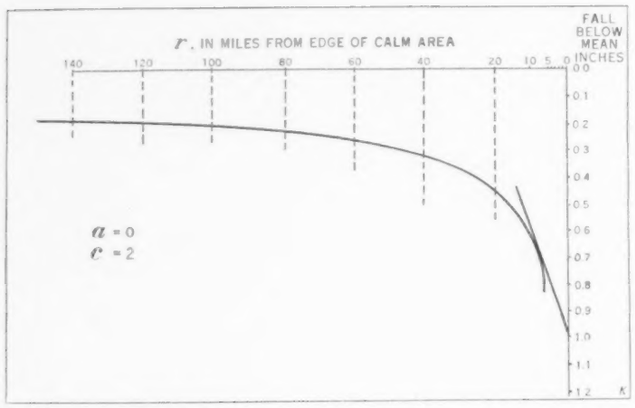

FIG. 3.—Relation of fall of pressure below the mean and the distance from the edge of the central calm. (See equation 1.)

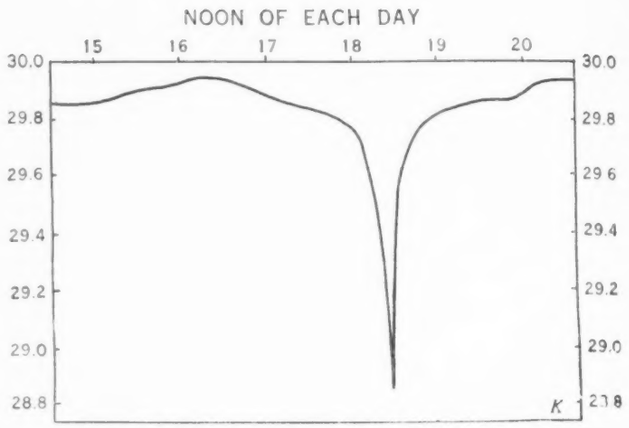

FIG. 5.—Barogram at Kingston for August 15-20, 1880, showing the rise two days before the hurricane of 1880, August 18, while the center was still 800-900 miles east of there.

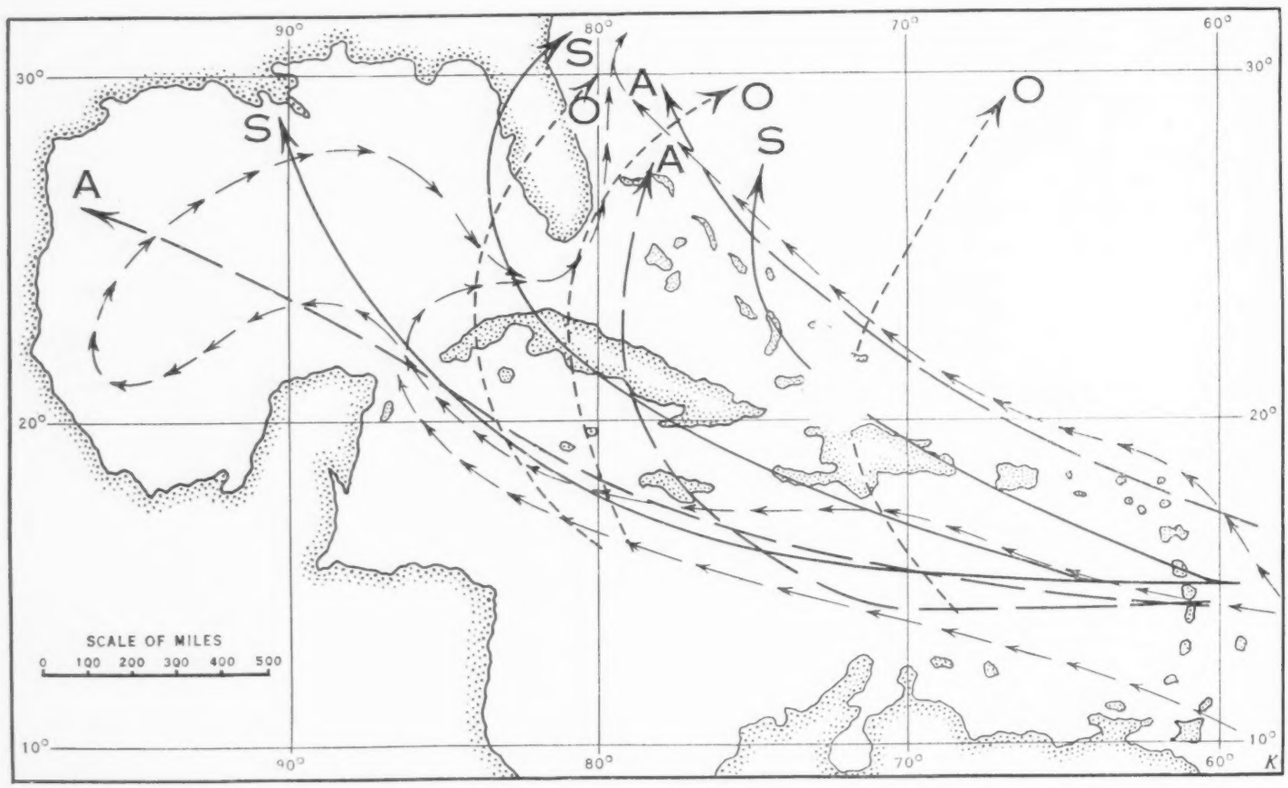

FIG. 4.—Ocean currents and average tracks of hurricanes in the West Indies and Gulf waters.

– – – – A—August tracks; — — — S—September tracks; - - - - - - O—October tracks; →→→ Ocean currents.

In the case of the hurricane, 1915, August 12 and 13, special means were adopted in W. R. No. 446 [2] to show that the isobars were circular; and similarly for the hurricane, 1916, August 15 and 16, in W. R. No. 460.

This circularity is no doubt due to the fact mentioned in the next paragraph; and it explains the absence of "trough" phenomena described in section (**17**).

Figure 2 represents the slightly oval isobars of an average cyclone moving toward the west-northwest along its axis, having the gradients steeper in front than in the rear, as was the case in the hurricane of 1903, August 11. The barometric pressure of each isobar is marked, the pressure in the calm central area being 28.9, or an inch below the mean; and the four small arrows show the direction of the wind at different points in accordance with with the results for small distances given in section (**11**). The trough or dividing line between falling and rising pressures as the cyclone moves forward, is in this case at right angles to the axis.

We shall measure gradients in decimals of an inch [barometric] per mile; and it will be found that between the isobars 29.7 and 29.5, the average gradient is only 0.003, while the gradient between 29.1 and the center is 0.05 inch.

Consequently while the fall is small when the center is 100 miles or so distant, and while it continues to fall very slowly at a place in its direction of motion, nearer the center the fall is very rapid and the "hurricane" rushes forward, as it were.

As this is all very important, figure 3 shows in another form the connection between pressure, or rather the fall of pressure below the mean, and the distance r from the edge of the calm area.

The curve in figure 3 may be taken to be the average of a large number of cyclones; and it represents the algebraic equation

$$\Delta p = \frac{c}{\sqrt{r-a}}, \qquad (1)$$

where Δp is the fall of pressure, corrected for diurnal variation, below the mean for the [illegible] of the year in question, and where c and a are constants for the same cyclone, with limitations, of course, as to front and rear and to time. The constant c may vary between 1 and 4 inches; and a may be as much as ± 18 miles. In figure 2, c has been taken to be 2, which often occurs, and a has been taken to be the zero.

When a is large and positive the gradient near the center is very steep; this often occurs among the small islands east of the Caribbean Sea; when a is large and negative, the gradient is small, and apparently the cyclone is either commencing or dying out.

It will be noticed in figure 2 that at a certain point the fall of pressure leaves the curve and follows the tangent to the lowest reading at the edge of the calm central area; and if a and c are known, and also the lowest pressure in the central area, it is very easy to draw the final tangent; but it is not so easy to find the exact point where the tangent touches the curve.

Let G be the gradient at any point in the curve measured in decimals of an inch of mercury per mile of the radius r; then by differentiating equation (1), or by a similar algebraic process (see Note A), we get

$$G = \frac{dp}{dr} = \frac{\Delta p}{2(r-a)}, \qquad (2)$$

[2] Jamaica weather reports are thus referred to.

Let Δp_0 be the fall at the center, let p_1 be the fall at the point where the tangent takes off, and let r_1 be the radius of this point or its distance from the calm central area; then

$$G = \frac{\Delta p_1}{2(r_1-a)} = \frac{\Delta p_0 - \Delta p_1}{r_1},$$

whence we easily obtain (see Note B),

$$\Delta p_1 = \tfrac{2}{3}\Delta p_0 - \tfrac{1}{2}a/c^2\Delta p_1^3, \qquad (3)$$

When a is zero, $\Delta p_1 = \frac{2}{3}\Delta p_0$; when a is a positive or negative quantity, equation (3) is a cubic, but it may easily be solved by approximation. And then r_1 may be found from the curve, or from equation (1), and G from (2).

These equations should not be pressed as though the cyclone functions exactly followed the law expressed by equation (1); they are rather intended to give a clear idea of what we may expect from a general average.

(**2**) *Tropical hurricanes are usually of much smaller dimensions than extra-tropical cyclones; but the central depression is much steeper and more pronounced in the former than in the latter.*

In the hurricane of 1903, August 11, the center passed along the middle of Jamaica, and the diameter of the storm area where the wind was above 50 or 60 miles an hour, was only 40 miles; [3] and outside a diameter of 100 miles the wind was not more than 20 miles an hour. But near the center the gradient was 0.04 inch per mile, and the wind reached hurricane force in gusts. And similarly for all our cyclones.

In the Windward and Leeward Islands the gradients near the centers are often much steeper, as already said, and the wind terrific; but the storm area is no larger.

(**3**) *Tropical cyclones have less tendency to split into two, or to develop secondaries than those in higher latitudes.*

When a cyclone develops, a minor depression is generally formed, which confuses the indications; the [minor] depression may move along the mid-Caribbean while the cyclone may either follow it or move northwestward; or a true secondary may be formed on the edge of the primary.[4]

(**4**) *A typhoon, which has come from the Tropics, can combine with a cyclone that has been formed outside the Tropics, and form a single new, and perhaps more intense, depression.*

(**5**) *No cyclone is an isolated phenomenon; it is always related to the general distribution of pressure in the latitudes where it is generated. The concentric circles, which are usually drawn to represent a cyclone, ignore the fact that a cyclone is always connected with and controlled by some adjacent area of high pressure.*

Of greater importance than the isobars are the curved lines, on a chart, showing the tracks of centers. Charts have been drawn showing on a single sheet the courses of a large number of West Indies hurricanes for each of the three "hurricane" months of August, September, and October, without reference to the particular pressure conditions which may affect each hurricane; and it is difficult to make out any average track or any rule affecting them.[5]

If, however, in Prof. Fassig's charts we attempt to group the tracks which pass south of Haiti (Hispaniola)

[3] In the U. S. MONTHLY WEATHER REVIEW for September, 1905, there are charts and a general description of this hurricane, sent to the REVIEW by the writer as the Jamaica Weather Service was closed between 1899 and 1907.

[4] As in the hurricanes of 1915, Aug. 12, and 1916, Aug. 15.

[5] "West Indian Hurricanes," Prof. E. B. Garriott; and "Hurricanes of the West Indies," Prof. O. L. Fassig, both published by the U. S. Weather Bureau, Washington.

and Cuba, those which pass for the most part north of those islands, and those which are intermediate, or which curve from the first group into the second, we obtain the following remarkable chart, figure 4, where the average tracks for the three groups in August, September, and October, are distinguished by the initials A, S, and O.

Importance must be attached to the place of commencement of each of these average curves, but none to the place where the arrowheads are marked to show the direction of motion—the curves may be continued northeastward to any extent.

There is a great deal in this chart to attract attention; most of the cyclones begin in about latitude 15°, where the rotational effect of the earth on moving currents is sufficient to set up cyclonic rotation; and most of them begin a few miles east of the Lesser Antilles where the great equatorial oceanic current is split in two, one part going into the Gulf of Mexico and the other part skirting the Bahama Islands.

Indeed the general effect of currents can not be overlooked; in figure 4 only the principal currents given by Lieut. Soley [6] have been marked down; and it will be noticed that the southern August and September tracks pass between the lower north and the south equatorial currents straight into the Gulf; that the intermediate August track commences similarly but curves toward the currents east of Florida; that the intermediate and northern September tracks lie between the two northerly equatorial currents; and that the northern August track simply follows the northernmost equatorial current past the Bahama Islands.

In October the pressure is generally high in the Southern States of North America; and the three October tracks apparently avoid the high pressure by curving sharply to the right.

Cyclones require vapor, which they turn into rain, thereby developing the heat necessary for their prolonged existence; and it seems probable that the supply is insufficient until the month of August, when the region of equatorial heavy rains between South America and Africa reaches as far north as latitude 15°.[7]

(6) *In all latitudes pressure often rises over a district just before the advent of a cyclone. The nature of this rise is at present obscure; but the character of the unusually fine weather under the high pressure is identical both within and without the Tropics.*

Figure 5 shows the rise in pressure at Kingston, Jamaica, two days before the hurricane of 1880, August 18, when the center was 800 or 900 miles away to the east; the mean height of the barometer was 29.9 inches at that time of the year; and the rise in pressure was 0.08 inch. Both the 16th and 17th were fine and calm in Kingston.

But the change in the weather is much more strongly marked in the interior parts of the island; during the autumnal months daily thunderstorms occur; the mornings are fine; clouds of the cumulus type gather and ascend in large masses, and break up with rain and much lightning. Consequently when it is found that there is no ascensional movement, that the sky remains almost clear, and that what clouds there may be apparently descend and dissolve, the unusual weather at once attracts attention.

(7) *In all latitudes a cyclone which has been generated at sea appears to have a reluctance to traverse a land area, and usually breaks up when it crosses a coast line.*

In figure 4 cyclones following the southern August track generally break up on reaching the coast of Mexico; cyclones following the middle September track are sometimes broken up by Haiti or Cuba; but a small island like Jamaica has no such effect.[8]

(8) *After the passage of a cyclone in any part of the world there is a remarkable tendency for another to follow very soon, almost along the same track.*

With reference to both the southern August and September tracks, it often happens that a small cyclone precedes a large and dangerous one; the last of the more noticeable occasions was 1915, September 24, as reported in W. R. No. 447. This tendency for a "secondary" to precede the primary, both taking the same course south of Jamaica, greatly confuses the indications as already stated in section (3).

(9) *The velocity of propagation of tropical cyclones is always small, and the average greatly less than that of European depressions.*

The centers of the cyclones of 1903, 1915, and 1916, all moved with a velocity of about 20 miles an hour; but as a rule the velocity is less, especially when the cyclones are generating. A number have generated south or southwest of Jamaica, when the centers appear to be stationary or rather to oscillate a little east and west before they move on their course with increased energy.

(10) *There is much less difference in the temperature and humidity before and after a tropical cyclone than in higher latitudes. The quality of the heat in front is always distressing in every part of the world.*

The temperature of the air during a hurricane at night is 5 or 6 degrees (F.) above the average (W. R. No. 446, p. 7); and the oppressive heat is at least disagreeable.[9]

(11) *The wind rotates counter-clockwise round every cyclone in the Northern Hemisphere; and everywhere as an in-going spiral. The amount of in-curvature for the same quadrant may vary during the course of the same cyclone; but in most tropical hurricanes the in-curvature is least in front and greatest in rear, whereas in England the greatest in-curvature is usually found in the right front. Some observers think that, broadly speaking, the in-curvature of the wind decreases as we recede from the Equator.*

In order to make a general study of the direction of wind and cloud drift with reference to the center of a cyclone, it will be necessary to adopt some simple system such as the following: At the place of observation D in figure 6 draw the wind-arrow or cloud arrow, the arrows being of course supposed to fly with the wind or cloud; and measuring angles from the east point of the horizon round by the north, call the wind angle α. Again at the place of observation lay off the direction of the center, and measuring the same way, call the angle β. Then if $\phi = \beta - \alpha$, ϕ is the angle between the center and the wind arrow.

[6] "The circulation in the North and South Atlantic Oceans"—supplement to the Pilot Charts—by Lieut. J. C. Soley, U. S. N., February, 1916.

[7] This theory of the mechanism of hurricanes is still the subject of discussion.—C. A., jr.

[8] In the hurricane of 1903, Aug. 11, the central area passed over Vale Royal near Kingston, and along the rough interior of the island to Montego Bay. These places are 85 miles apart, but the lowest barometers were exactly the same at both places, namely, 28.93 inches; and there was the same estimated velocity of the wind.

[9] I have been unfortunate with thermometer screens during hurricanes. I have them clamped to wooden stands firmly attached to the ground: but something has to give way, and the thermometers are either displaced or broken.

The following diagram and table will be useful:

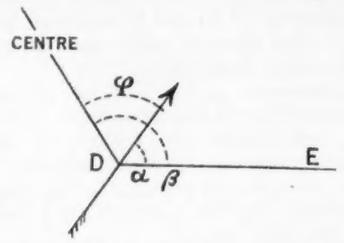

FIG. 6.—Diagram illustrating system of naming angles for the wind-arrow at the station *D*.

Wind or cloud drift.

From—	α	From—	α
	°		°
n	270	s	90
nnw	292	sse	112
nw	315	se	135
wnw	338	ese	158
w	0	e	180
wsw	22	ene	202
sw	45	ne	225
ssw	68	nne	248
s	90	n	270

Similarly for cloud drift:

For stratus, $\phi_1=\beta-\alpha_1$.
For cumulus, $\phi_2=\beta-\alpha_2$.
For cirrus, $\phi_3=\beta-\alpha_3$.

The length of the arrow, or the number of feathers, may be arranged to indicate the velocity of the wind according to Beaufort's scale.

Now the average course of the center of cyclones in the West Indies between longitudes 60° and 75° is from east-southeast to west-northwest (see fig. 4); and the observations of the wind in Jamaica were divided among the following quadrants:

1. ese, and β between 300° and 29°.
2. nne, and β between 30° and 119°.
3. wnw, and β between 120° and 209°.
4. ssw, and β between 210° and 299°.

Moreover the observations were further divided into two groups according to distance, the first group containing those made when the center was at a considerable distance, say 300 or 400 miles, and the second group containing those made when the distance was small and less than 100 miles.

But over the Caribbean Sea there is a constant drift which blows over Jamaica from the east-southeast during the hurricane months of August, September, and October; and although on the plains it is subject to the irregularity of the sea- and land-breezes, yet at higher elevations it is much more regular; and for the general reduction of observations it was assumed that the constant drift flows at the rate of 8 miles an hour.

In figure 7 let *D* be the place of observation, and *DE* a line drawn toward the east point of the horizon; then if *DA* be the drift from east-southeast, and *DB* the observed wind from northeast at 10 miles an hour, by joining *AB* and completing the parallelogram we find that the cyclonic wind, or wind due to the cyclone alone, is *DC* or a wind from north at 10½ miles an hour.

The observations were taken from 13 of the more suitable cyclones which were apparently unaffected by secondaries, or other cyclones at a distance; they were formed into groups, and the general drift was eliminated

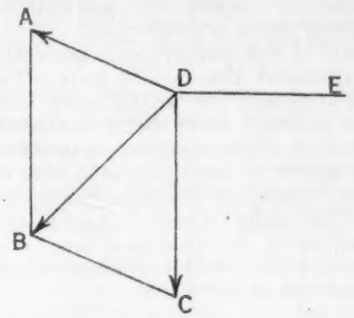

FIG. 7.—Parallelogram of wind-velocities at the station *D*.

from the groups by means of the parallelogram of velocities. The results are given in the following table:

Quadrant, or bearing of center.	Angle φ between wind arrows and center.		
	Distance large.	Distance small.	Average distance.
	°	°	°
(1) ese	44	62	53
(2) nne	72	77	74
(3) wnw	44	68	56
(4) ssw	36	47	41
Means	49	64	56

The first thing that we notice is that the angle is larger when the distance is small; that is to say, the motion becomes more circular as we approach the center.

The next thing we notice is that while the angles in quadrants (1) and (3) of the table are equal, or nearly so, the angle is a maximum in (2) and a minimum in (4). The rule here seems to be that when the center is approaching in (1), or receding in (3), the angle is about the same, namely, 44° for large distances, and 65° for small. But when the center is passing in (2), the wind arrow lags behind the moving center; and when the center is passing in (4), the wind arrow lags in front, so that the angle is too large in (2), and too small in (4). The wind arrows for small distances are marked in figure 2.

Now a large number of cyclones pass to the northwest of the British Isles on a northeasterly course, so that "the greatest incurvature on the right front" in England corresponds with wind arrow in Jamaica lagging in front of the moving center (4). And as 49° is the average angle for large distances, the in-curvature is 41° in Jamaica, while it is only about 20° for the cyclones farther north [10] so that the in-curvature "decreases as we recede from the Equator."

For some details respecting these important conclusions reference must be made to the Quarterly Journal of the Royal Meteorological Society for July, 1916, and January, 1917, but even there the voluminous observations had to be summarized.

(12) *The velocity of the wind always increases as we approach the central calm in a tropical cyclone; whereas in higher latitudes the strongest winds and the steepest gradients are often some way from the center. The portion of a cyclone which is of hurricane violence forms, as it were, a kernel in the center of a ring of ordinarily bad weather. In this peculiarity tropical cyclones approximate more to the type of a whirlwind tornado, but the author does not think*

[10] *Great Britain. Meteorological Office.* "Barometer Manual (Official)," 1912, p. 30. London. Wyman & Sons.

that a cyclone is only a highly developed whirlwind, as there are no transitional forms of rotating air.

The first part of this paragraph is perfectly true, but I do not understand the middle part. The wind increases as we approach the central calm, which may be a few miles or as much as 38 miles in diameter, so that a ring of wind of hurricane force surrounds the calm center; the diameter of the storm area may be 100 miles or so, and the diameter of the area under cyclonic influence may be 1,800 miles or more. And as cyclones commence by rotation of the wind over large areas, there is nothing to connect them with tornadoes, whose diameters may not exceed 100 or 200 yards.

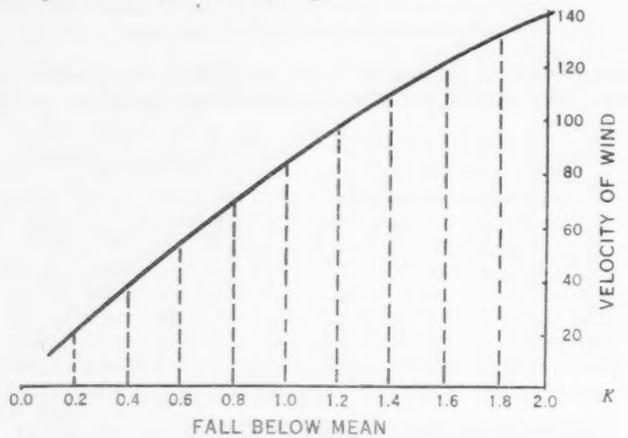

FIG. 8.—Curve expressing relation between the fall of the pressure below the mean and the velocity of the wind.

There is a close connection between the velocity of the wind and the fall of pressure. Let v be the velocity in miles per hour corrected for the constant east-southeast drift as explained in section (**11**); let Δp be the fall of pressure below the mean for the time of year and hour of the day, as before; then

$$v = 98\Delta p - 48\Delta p^2, \tag{4}$$

In the table below the first 5 results of observation were given by the same researches which gave the angle between the direction of the center and the wind arrow; the sixth was taken from observations in Jamaica given below on page 583; and the last result was taken from the observations at New Orleans during the hurricane of 1915, September 29, which passed south of Jamaica and apparently developed as it crossed the Gulf of Mexico.[11]

Δp.	Velocity in miles per hour.		Remarks.
	Observed.	Computed.	
Inches			
0.10	10	10	
0.22	20	21	
0.45	41	41	See table, p. 581.
0.56	52	50	
0.70	55	62	
1.04	83	87	Observations in Jamaica.
1.80	130	131	New Orleans, Sept. 29, 1915.

All these velocities assume that the wind blows steadily, and is registered by a Robinson anemometer during a considerable interval of time; but the wind in a cyclone blows in gusts, as described in section (**15**); for velocities of 20 and 30 miles an hour the gusts are often twice these figures; for velocities of 50 and 60 miles an hour the gusts are about 1½ times these figures; and they become appalling as the center draws near.

The wind increases in velocity as we approach the central area, according to the rule above or to some modification of it, and finally the velocity is such that the hydrodynamic equation is satisfied, and the "centrifugal force" [12] of the rotating air is equal to the pressure toward the center produced by the gradient, and this determines the radius of the calm area, r_0.

Taking the well-known equation

$$p = k\rho(1 + 0.003665t)$$

where p and ρ are the pressure and density of the air, and t its temperature centigrade, if we take $t = 29°$ at the center, and if we take miles and hours as the units of space and time, $k = 392{,}200$ (see Note C) and the equation becomes

$$p = 433{,}900\rho.$$

We thus have, supposing the center to be at rest,

$$\frac{v^2 \sin^2\phi}{r_0}\rho = \frac{dp}{dr} = G,$$

or

$$v^2 = 433{,}900\frac{Gr_0}{p\sin^2\phi}. \tag{5}$$

We have only two good cases to test this equation; when the central area passed over Brandon Hill, 1903, August 11, and when the central area passed over Negril Point Lighthouse, 1916, August 15–16.

BRANDON HILL, AUGUST 11, 1903.[13]

	Immergence.	*Emergence.*
	9 a. m.	10 a. m.
r_0, 8 mis	8 mis.	
G, (8:45ª–9:15ª) 0.040 in	(9:42ª–10:15ª) 0.025 in.	
p, 29.2 in	29.2 in.	
α, 248°	90°	
ϕ, 90	70	
v, 70 obs., 69 comp	60 obs., 58 comp.	

NEGRIL POINT LIGHTHOUSE, AUGUST 15–16, 1916.[14]

	15th, 10:30 p. m.	16th, 1:30 a. m.
r_0, 19 mis	19 mis.	
G, (10ᵖ–11ᵖ) 0.008 in	(1ª–2ª) 0.013 in.	
p, 29.1 in	29.2 in.	
α, 292°	135°	
ϕ, 50	26	
v, 60 obs., 62 comp	96–120 obs., 140 comp.	

The last computed velocity is too large; but if ϕ had been taken to be 34° instead of 26°, the computed velocity would have agreed with the observed velocity, which was about 108 miles/hr. The difference is due to an irregularity in the wind, which at first blew too nearly toward the center. Such irregularities will always occur, and these computations may be considered satisfactory.

If instead of taking two special cases we had taken all the observations of velocity near the calm area, which are here given, the mean velocity of 83 miles nearly agrees with the velocity computed by equation (4).

[11] U. S. MONTHLY WEATHER REVIEW, September, 1915, 43:472.

[12] The Editor prefers the more accurate expression "centri ugal tendency."

[13] MONTHLY WEATHER REVIEW, September, 1905.

[14] Jamaica Weather Report No. 460.

Date.	Station.	p.	v.
		Ins.	*Mls./hr.*
1880, August 18	Kingston	28.85	80
1903, August 11	Vale Royal	28.93	70
1903, August 11	Brandon Hill	28.93	60-70
1912, November 18	Kempshot	29.02	80-120
1912, November 18	Negril Point	28.49	80-120
1916, August 16	Negril Point	29.07	60-96 or 120
Means		28.88	83

And as the average pressure was 29.92 [inches] for these dates, we have $\Delta p = 1.04$, and $v = 87$ from (4), which are well within the probable error of observation.

But taking the observed value from (5) we have $Gr_0 = \frac{1}{2}\sin^2\phi$, which gives a general idea of the relation between G, r and ϕ, at the edge of the central calm. When $\sin\phi$ is 1, or otherwise constant, the smaller the radius of the calm area the larger the gradient, and vice versa. Such small areas and large gradients often occur among commencing cyclones to the east of the Caribbean Sea; and for an example of a large area and small gradient we can refer to the Jamaica hurricane of 1916, August 15–16.

Now, while $v\sin\phi$ is the velocity of the air rotating in a circle round the center, $v\cos\phi$ is the velocity of the air pouring into the calm area from all sides. The air here is hot and dry, as described in section (**16**). Its high temperature will cause it to ascend and to partly dissolve the clouds, so that in the daytime patches of blue sky may be seen between them, forming what is called the "bull's-eye". Constant action is hereby maintained, more air is drawn in, more vapor condensed into rain, more heat developed. In fact, a "machine" is established, which finds fresh supplies of vapor as the cyclone travels sometimes thousands of miles over the surface of the sea toward the British Isles or Iceland.

(**13**) *The general circulation of a cyclone, as shown by the motion of the clouds, appears to be the same everywhere.*

All over the world unusual coloration of sky at sunrise and sunset is observed not only before the barometer has begun to fall at any place, but before the existence of any depression can be traced in the neighborhood.

Cirrus appears all round the cloud area of a tropical cyclone, instead of only round the front semicircle as in higher latitudes. The allinements (!) of the stripes of cirrus appear to lie more radially from the center in the Tropics, instead of tangentially to the isobars, as indicated by the researches of Ley and Hildebrandsson in England and Sweden, respectively.

The general character of the cloud all round the center is more uniform in than out of the Tropics; but still the clouds in rear are always a little harder than those in front.

The broad current of air over the West Indies constituting the "trade wind" reaches from the surface of the sea 4 or 5 miles upward, as is shown by the daily movements of large and well-formed cumuli.

The dividing plane between the upper part of this current and the lower part of the next layer or stratum is strongly marked in Jamaica from May to October. The following account was given by the writer in 1896 in Jamaica Weather Report No. 193:

> When rain begins to fall from a large cumulus, a quantity of cloud is poured into the air from the top of the cumulus, as smoke from a factory chimney; this takes place in all parts of the world when rain falls from cumuli, but in the Temperate Zones only a little *false cirrus*, or cirriform cloud, is thrown off. In Jamaica the process is on a gigantic scale, and the cloud is spread out as a sheet far and wide so as to shade the land for some hours from the direct rays of the afternoon sun. It is therefore a common cloud in the west-central district of Jamaica during the summer and autumn months.
>
> Its texture at first is thick and woolly, but as it spreads the sheet becomes thinner; it then generally settles down as stratus, and finally it disappears a little after sunset, leaving the evening sky perfectly clear. As it spreads and settles the typical features of cirro-stratus and alto-stratus may sometimes be seen, but such features are not lasting.

Abercromby in his "Instructions for Observing Clouds"[15] described strato-cirrus as follows:

> A cloud identical in general structure with cirro-stratus only denser and at a lower level. * * * The thin flat layer of cloud is drawn out at the edges into fibers, which shows that the cloud is a compound of cirrus and stratus; but as the cloud is dense and comparatively low, we know that it ought to be called strato-cirrus.

Now, this strato-cirrus is formed at great elevations; some measures in Jamaica made it as much as 6 miles; and it forms the dividing plane between the trade-wind current and the higher regions of cirrus. Indeed, it is curious to watch the large cumulo-nimbus moving along from the east-southeast, and the strato-cirrus pouring from the [its] top in a totally different direction; but the absence of cirrus under these really fine-weather conditions makes it impossible to say whether the drift of the strato-cirrus is that of the cirrus or not.

Consequently in the trade-wind current we have stratus and cumulus and all their compounds moving from the east-southeast together with the wind; and above these we have cirrus and cirriform cloud moving from any point of the compass, but from the west as a general average for the West Indies.

Regular observations are made in Jamaica at 7 a. m. (75th M.), but for the proper observation of cirrus the time should be about an hour earlier, or near sunrise; and when a cyclone is approaching a constant watch should be kept until strato-cumulus or other lower clouds begin to cover the sky; but as there is often a fine day with a slight rise in pressure before the approach of a cyclone (sec. **6**), as night must often intervene, as lower clouds soon move up and showers begin to fall, and as showers soon pass into rain squalls, there are remarkably few observations of cirrus under cyclonic influence among our notes and records.

Again, as in the case of the wind, we have to select those cyclones which are not interfered with by secondaries or other cyclones at a distance, and we must also know accurately the positions of their centers.

On this account my early work on this subject was considered unsatisfactory, but of course the lower clouds were much the same as the wind; indeed, among the hills the cloud level lowers under cyclonic influences so that the hills are capped with stratus, and the wind and fog move together; as seen from the plains the stratus follows the law of vertical succession. But the cirrus not only moves from the center but even farther around than the Habana observations indicated.[16]

It is here proposed to consider cloud motion under cyclonic influence as observed in the hurricanes of 1903, 1915, and 1916, of which the records and charts are published but to which we may now add a few cloud observations taken at irregular hours.

In the following table, β is the direction in which the center lies from the place of observation measured from east around by north, and r is the distance in miles, both taken from charts; ϕ' is the angle between the observed wind arrow and the center; ϕ is this angle corrected for the constant east-southeast drift; ϕ_1, ϕ_2, ϕ_3 are the angles between the arrows flying with the stratus, cumulus, and cirrus, and the center; in the last column β has been deduced from two or three of the functions, ϕ, ϕ_2, ϕ_3.

[15] Ed. Stanford, London, 1888.

[16] West Indian Hurricanes, by E. B. Garriott. Washington, 1900. p. 18.
Relation of the Movements of the High Clouds to Cyclones in the West Indies, by John T. Quin. MONTHLY WEATHER REVIEW, Washington, 1907, 35: 215–219, 510–511; 1909, 37:134–141.

Cloud-drift and the center.

Date.	Hour.	Place.	Center.		Wind.		Clouds.			β deduced.	Notes.
			β	r	ϕ'	ϕ	ϕ_1	ϕ_2	ϕ_3		
			°	*Miles*	°	°	°	°	°	°	
1903.											
Aug. 10	7 a. m.	Sav-la-mar	350	550	125	83	.....	.....	(125)	.....	1 cir.[1]
10	6 p. m.	Brandon Hill	350	315	148	32	.....	.....	215	358	1 cir.
10	3 p. m.	Vale Royal	350	180	.....	.....	.....	125	204	342	Str-cum; cir-str. and cir. At Christiana in Manchester cirrus bands were seen to stretch from N. to. S. across the sky about this time.
11	4 a. m.	do	350	26	35	31	.....	125	181	360	Str.-cum; cir-str. and cir.
1915.											
Aug. 12	7 a. m.	Morant Point	345	280	75	65	75	.....	.....	.....	10 str.-nimb.
12	7 a. m.	Kingston	346	322	76	50	121	76	211	356	4 cum; 1 cir.
12	11 a. m.	do	348	246	78	58	123	100	213	347	1 cum; 6 cir-str. and cir.
12	3 p. m.	do	352	183	82	56	127	.....	.....	.....	10 str.-nimb.
12	7 a. m.	Kempshot	344	402	74	52	74	.....	.....	.....	10 str.
12	10 a. m.	do	346	345	98	76	98	121	211	333	2 fr.-cum: cir-bands with motion along their length. Thin cir-veil over blue sky.
12	11 a. m.	do	346	326	98	65	121	.....	.....	.....	
12	2 p. m.	do	348	274	.....	.....	.....	123	.....	.....	4 cum.
12	5 p. m.	do	350	222	.....	.....	.....	125	170	358	Cir-bands NW. and SE. moving from E. across 10 cir-str. Z.
12	3 p. m.	Negril Point	351	295	81	59	81	.....	.....	.....	Scud.
1915.											
Sept. 27	11 a. m.	Kempshot	154	632	19	68	19	.....	176	160	Cir-band moving along its length.
1916.											
Aug. 14	7 a. m.	do	343	750	163	35	.....	.....	208	349	5 cir.
14	3 p. m.	do	343	600	141	25	.....	.....	208	354	10 cir-str.[2] Great haze over the land like that over the sky.
15	3 p. m.	Kingston	329	62	59	47	59	.....	.....	.....	10 nimb.
15	4 p. m.	do	324	42	54	28	.....	99	.....	345	Cum-nimb.
15	5 p. m.	do	317	22	25	(12)	.....	92	.....	.....	Cum-nimb.[3]
15	9 p. m.	do	178	42	43	48	43	.....	.....	.....	Str.
15	6 p. m.	Kempshot	327	71	102	78	102	.....	.....	.....	10 str.
15	6 p. m.	Negril Point	342	97	72	54	72	.....	.....	.....	10 nimb.
29	6 a. m.	Kempshot	338	800	158	81	.....	.....	203	318	2 cir.
30	6 a. m.	do	338	340	136	83	136	.....	203	322	Cir-band seen among 10 str.
30	11 a. m.	do	347	240	145	49	.....	145	189	342	Cir-band moving along its length.
Means						56	.....	113	199	.....	

[1] Some cirriform cloud had apparently settled down to the level of the middle class.
[2] Probably dense cirrus.
[3] Kingston was just at the edge of the central area and the wind, which was only 28 miles, was blowing almost straight in. See section (12).

It will be noticed that with two exceptions the center was always in the east-southeast quadrant; this is of course the most important quadrant for Jamaica, but a more general analysis could have been wished (see Note D).

With regard to cirrus, taking the mean of ϕ_3 to be 199°, the greatest difference from the mean is 29°, and the average difference is 13°; cirrus is therefore somewhat more reliable than the wind or cumulus.

And when the three—wind, cumulus, and cirrus—or any two of them, are observed, and β deduced and compared with β taken from the charts, it will be found that the greatest difference is 21°, and that the average difference is 10°; so that greater accuracy is obtained when two or three aerial currents are observed, as might have been expected.

There is as much cirrus in the rear of a West Indies cyclone as there is in front; often there is more; and cirrus moves away from the center after it has passed in exactly the same manner as when it approached.

And with reference to the Habana observations, when a cirrus band moves along its length then the direction of the band indicates the position of the center; otherwise the position of the center must be inferred from the motion of a point on a band; and as many of these bands are very uniform, it is often difficult to find a well-marked point.

The present cloud results are in close agreement with those found many years ago, to which reference was made above; and consequently these results may be said to be based on observations extending over 30 or 40 years.

With regard to strongly marked colors in the sky at sunrise and sunset, it were greatly to be wished that they were always to be observed before a cyclone, or before the pressure begins to fall; but this is not the case; sometimes the strongest colors appear in connection with quite small depressions; and sometimes with large cyclones they hardly appear at all.

(**14**) *Everywhere the rain of a cyclone extends farther in front than in rear. Cyclone rain has a specific character quite different from that of showers or thunderstorms; and this character is more pronounced in tropical than in extra-tropical cyclones.*

Thunder or lightning are rarely observed in the heart of any cyclone, and their absence is a very bad sign of the weather. Thunderstorms are, however, abundantly developed on the outskirts of tropical hurricanes.

In section **6** reference was made to the daily thunderstorms in the central parts of Jamaica during the autumnal months; and in the last paragraph it was stated that on the approach of a hurricane the hills are capped with clouds, that lower clouds soon cover the sky, and that showers begin to fall which pass into rain squalls; and these are both distinct from our winter "northers," when the steady wind from the north sweeps across the sea and throws down any quantity of rain on the opposing hills on the north side of the island.

So cyclonic rain is very distinct; and while thunderstorms may occur on the outskirts of a hurricane, they are not a feature of our cyclonic weather; and in this way when rain and wind set in during the autumnal months the absence of thunderstorms may be "a very bad sign" to the community at large.

(**15**) *Squalls are one of the most characteristic features of a tropical cyclone, when they surround the center on all sides; whereas in Great Britain squalls are almost exclusively formed along that portion of the line of the trough which is south of the center and in the right rear of the depression. As, however, we find that the front of a British cyclone tends to form squalls when the intensity is very*

great, the inference seems justifiable that this feature of tropical hurricanes is simply due to their exceptional intensity.

As the central area of a cyclone approaches, the squalls become terrific and apparently it makes no difference on which side of the area the observer may be. In the August hurricane of 1915, the squalls at Kempshot were as bad seven hours after nearest approach as they were an hour and a half after, the center moving away at the rate of 19 miles an hour.

It so happens that a visitor from Ireland in 1815 experienced the Jamaica hurricane in October that year, and wrote a brief note on the subject some years after,[17] in which he refers to the squalls more particularly. The house he was in at Hope Bay gave way, and shelter had to be obtained elsewhere; it was then that "these gusts of wind appeared to roll on like volumes of water, the trees and bushes crashing beneath their pressure, one of these wind waves coming on the heels of another."

(**16**) *A patch of blue sky in the center of a cyclone, commonly known as the "bull's-eye," is almost universal in the Tropics, and apparently unknown in higher latitudes. This blue patch does not apparently always coincide exactly with the barometric center. The author's researches show that in middle latitudes the formation of a "bull's-eye" does not take place when the motion of translation is rapid, but as this blue space is not observed in British cyclones when they are moving slowly, it would appear that a certain intensity of rotation is necessary to develop this phenomenon.*

Elsewhere, at page 20 of this article, Abercromby wrote:

Lastly in the vortex of the typhoon we find the "bull's-eye," or calm clear spot a few miles in diameter, surrounded on all sides by the fury of the hurricane. Many accounts received agree in saying that light cirri are usually seen over this area, that near land this space is full of birds taking refuge from the terrific surrounding squalls, and that the heat is suffocating. During the passage of the vortex over Manila on the 20th October (1882), the thermometer rose rapidly and the relative humidity decreased to an extent hardly known in the driest months. The universal exclamation was "The air burns."

In the succeeding typhoon, November 4 and 5, no such central heat was observed, but the intensity of the cyclone was much less.

The instrumental observations at Manila on these two occasions are almost unique, but there is no doubt that a clear hot central spot is a normal feature of tropical cyclones. The oppressive heat and great dryness would probably point to the existence of a slight down draft in the core of the cyclone. It is extremely difficult to form a definite conception of such a system of circulation, for there is not the slightest doubt that the main mass of air in the center of a cyclone is rising.

As remarked in section (**12**), the air rushes into the central area from every point of its limiting circle with a velocity of $v\cos\phi$, producing an ascending volume rather than current, so that the ascensional motion can hardly be observed.

With regard to the great central heat occasionally felt in a hurricane which passed over one of the Lesser Antilles a few years ago, it was reported that at a certain place the people were deluged with "hot water" instead of rain.

The central calm area of the Jamaica hurricane of 1903, August 11, was 10 miles in diameter; the wind in this area was light and variable as to direction; the clouds were light cumuli, with patches of blue sky among them, and they were rotating slowly in the same direction as the hurricane outside the calm area. I did not notice any great increase in temperature.

In the hurricane of 1916, August 15–16, the diameter of the central area was as much as 38 miles, but it was "calm" only in comparison with the hurricane outside. The area, however, did not pass over me.

The following account of the calm area of cyclone B, November 18, 1912, was given in Jamaica Weather Report No. 411, page 4:

> The calm central area of cyclone B was as much as 20 miles in diameter, and as it passed over any place toward evening the cloudy sky was lit up by a bright orange glow. Many allusions are made to it among the notes sent me by different correspondents; at Kempshot the calm began at 3 p. m., and at 3:30 p. m. patches of blue sky were seen high up toward the southwest, and also toward the north; later on the clouds had a misty churned-up appearance, but they were high above the ground; at 5:15 p. m. fog came on, or rather the clouds came down to our level of 1,800 feet, and at 5:40 p. m. the fog had an extraordinary orange color, not in any particular direction, but uniformly colored in every direction; at 5:45 p. m. it was exceedingly bright; at 5:55 p. m. the wind recommenced, from northwest with rain, all the color disappeared, the squalls got stronger, and the second hurricane was upon us in full force at 6:35 p. m. Now sunset occurred at 5:14 p. m. standard time of the 75th meridian, the time used recently in Jamaica; so that the color was brighter half an hour after sunset, when also the calm area passed away from Kempshot; so that the color must be connected with the evening colors after sunset and the central calm area. If the latter could be regarded as an enormous cylinder reaching above the dark thick clouds of the surrounding hurricane, its top might easily be so illuminated as to throw the glow down the cylinder and to distribute it uniformly. I am not aware that the appearance has ever been seen before.

On this occasion there was enough "intensity of rotation" to satisfy anyone—120 miles an hour. The wind instruments were destroyed, and this estimate was made from the pressure required to hurl about a terrace a number of heavy *cubical* flower pots, out of which the plants were blown early in the proceedings.

(**17**) *The trough phenomena—such as a squall, a sudden shift of wind, and change of cloud character and temperature just as the barometer turns to rise, even far from the center—which are such prominent features in British cyclones, have not been even noticed by many meteorologists in the Tropics. The author, however, shows that there are slight indications of these phenomena everywhere, and he has collated their existence and intensity with the velocity of propagation of the whole mass of the cyclone.*

Reference was made in section (**1**) to the circularity of most of the cyclones which have passed over Jamaica; and, of course, we would hardly expect any "trough phenomena"; but it often happens that near the time of lowest pressure, or when the barometer begins to rise, there is a remarkable drop in pressure and a heavy squall, but without any shift in the wind.[18]

(**18**) *Every cyclone has a double symmetry. One set of phenomena, such as the oval shape, the general rotation of the wind, the cloud-ring, rain area, and central blue space, are more or less related to a central point. Another set, such as temperature, humidity, the general character of the clouds, certain shifts of wind, and a particular line of squalls, are more or less related to the front and rear of the line of the trough of a cyclone.*

The author's researches show that the first set are strongly marked in the Tropics, where the circulating energy of the air is great and the velocity of propagation small; while the second set are most prominent in extra-tropical cyclones,

[17] A Voyage to Jamaica, by *James Kelly*. Belfast, 1838.

[18] Hurricane of 1916, Oct. 12, see Jamaica Weather Report No. 462, p. 5, footnote; Hurricane of 1916, Nov. 8, see Jamaica Weather Report No. 464, p. 4.

where the rotational energy is moderate and the transitional velocity great.

The first set of characteristics may conveniently be classed together as the rotational; the second set as the translational phenomena of a cyclone.

(**19**) *Tropical and extra-tropical cyclones are identical in general character, but differ in certain details, due to latitude, surrounding pressure, and to the relative intensity of rotation and translation.*

MOTION OF TRANSLATION AND ROTATION.

According to section (**11**) it might be imagined that a cyclone consisted of a number of spiral rings of wind rotating more and more rapidly as they approached the center, while the whole mass of air moved onward.

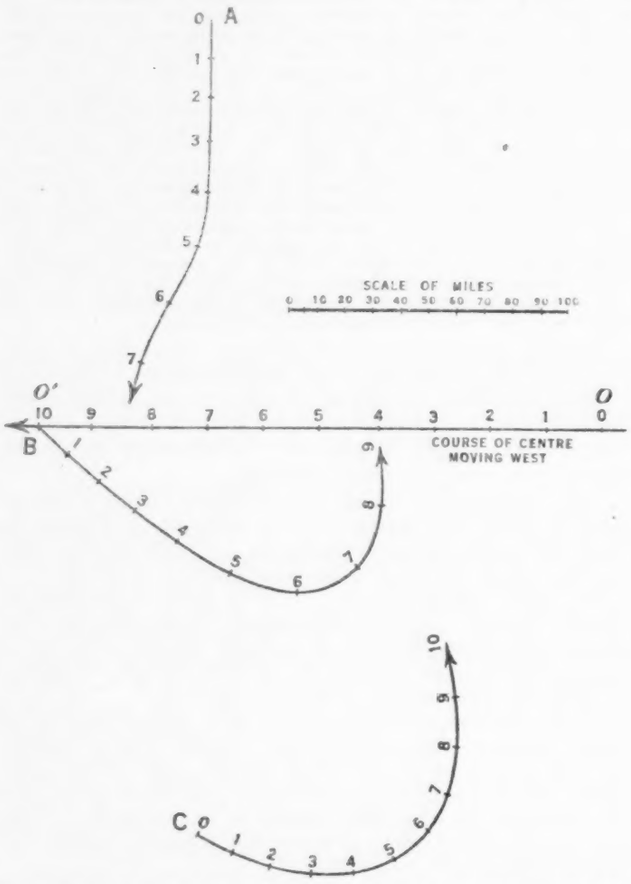

FIG. 9.—Tracks of portions of air at *A*, *B*, and *C*, relative to the center moving from *O* to *O'*.

Consequently if the cyclone were moving toward the west the wind at a point north of the center would be moving with its rotational velocity *plus* V, the velocity of translation of the center; and the point at the same distance south of the center would be moving with the same rotational velocity *minus* V; and when V is large, say 20 miles an hour, the effect on the wind north and south of the center will be strongly marked. And of course every point on a spiral would be affected one way or another.

Such a system does not represent a cyclone at all. Sir Napier Shaw, F. R. S., director of the British Meteorological Office, has shown that if each portion of air within a cyclone simply moves at any instant in accordance with its position and distance from the center at that instant, then the effect of the motion of the center is to make the air sweep in from the north to the central line and then sharply turn round the center, or even get caught by the hurricane ring surrounding the calm central area; while the air south of the central line hardly approaches, or even moves away from the center.

In figure 9 let us consider the three points A, B, C, in front of an advancing cyclone whose center is O, all at the distance of 200 miles from the center; at A the center lies to the southeast, at B to the east, and at C to the northeast.

The fall of pressure corresponding with r must be taken from equation (1), in which we shall take $a=0$, $c=2$; then v is known from equation (4); and the direction of motion for each quadrant is given in the table in section (**11**).

Take V, the velocity of the center, to be 20 miles an hour; and then we can roughly draw the lines and curves in figure 9, showing the positions of the center and of A, B, and C, from each hour from 0 to 10.

It will be seen that A is drawn into the hurricane ring round the center, that B, moves round the center and that C after describing a short curve is left behind.

Generally speaking, in figure 9 we see that the faster the motion of the center, the faster the air north and south of the central line changes its direction, while the velocity depends on r, the distance from the center, and its functions Δp and G.

Now, while the center moves forward, the oval isobars also move forward, not by pushing the air in front but by a wavelike transmission of pressure; and thus from moment to moment the whole cyclone may be imagined to take up fresh positions along its line of advance without any part of the air being moved by that advance.

Consequently, when the central area passes over a place where there is no gradient and no wind due to cyclonic rotation, there is also no wind due to cyclonic translation, although the cyclone may be moving at the rate of 20 miles an hour.

The effect of passing into the central area, from hurricane to fine weather in the course of a few minutes, is always surprising; and the damage done must always cause anxiety as to the coming hurricane when passing out.

APPLICATION OF RESULTS TO ACTUAL CYCLONES.

In "The Observer's Handbood," issued annually by the Meteorological Office, London, or in "Hints to Meteorological Observers,"[19] will be found full information respecting meteorological instruments and their management, and a great deal of valuable information, so I shall only remark that mercurial barometers should be used instead of the more convenient aneroids, for the simple reason that the latter soon get out of order; moreover they have to be continually compared with a mercurial standard, as absolute pressures are required.

Good mercurial barometers are necessary in dealing with cyclones at a distance and small depressions near at hand; they must be read to the nearest 0.002 inch, and the usual four reductions to standards of temperature, elevation, gravity, and Kew for instrumental error, must be made.[20] Again the readings must be corrected for di-

[19] *W. Marriott*, Ed. Stanford, London.

[20] The United States Weather Bureau groups these four under the two heads "Instrumental error" and "altitude" corrections. The mercurial barometer is read to 0.001 inch.—C. A., jr.

urnal variation of pressure which goes on regularly hour after hour, storm or no storm, for this variation is as large as the fall due to the distant disturbances we want to measure. After these corrections the third decimal figure can not of course be depended on, but it should be retained until the reduced reading has been subtracted from the average pressure for the time of the year, and the fall below mean obtained, and then the third figure should be rejected.

With regard to wind instruments, Robinson's anemometer is most valuable in giving the average velocity for short intervals of time; and it is to these velocities that our formulæ always refer. It can also be used in checking estimated velocities during a considerable length of time; but when the velocity is very great and the gusts tremendous, it seems doubtful whether any instrument [in general meteorological use] can measure them correctly.

For daily registration of cloud observations in the Tropics there should be three columns headed "lower," "middle," and "upper," for stratus, cumulus, and cirrus; and when the cloud forms become mixed as a storm comes on, it may at least be possible to refer them to their proper columns. But fracto-stratus and fracto-cumulus are sometimes very much alike when driven before a rising gale; and either dense strato-cumulus or dense cirriform cloud forms the overhead canopy.

With regard to cirrus and cirro-stratus, the observers in Jamaica, including myself, have generally confined cirrus to its definition: "Detached clouds of delicate or fibrous appearance often showing a feather-like structure" etc. Consequently we have applied cirro-stratus to include dense cirriform sheets; but the definition of cirro-stratus is: "A thin whitish sheet of cloud" etc., and I am inclined to think that the latter definition should be preserved, noting "dense cirrus" when necessary; "cirrus bands" forming a connecting link between the two forms.

In this case cirro-stratus will be seen for a short time only; and the sequence for an advancing cyclone will be: cirrus according to definition, cirrus-veil, cirro-stratus, cirrus bands, and dense cirrus. But of course stratus, or strato-cumulus, prevents, as a rule, any such complete sequence from being observed.

We shall now consider a few cases.

EXAMPLE 1.

August, 1915, Kempshot. Mean barometer, 29.928 inches.

	Ins.	
9th 7 a. m.,	29.978	
9th 3 p. m.,	.997	
10th 7 a. m.,	.976	Fine weather; usual winds and clouds.
10th 3 p. m.,	.967	
11th 7 a. m.,	.942	
11th 3 p. m.,	.888, very fine, calm, clear.	
11th 7 p. m.,	.859, very fine clear evening.	
12th 7 a. m.,	.788, wind, north, 15 miles an hour; 10/10 str., north.	

It was now apparent that there was a cyclone to the east, and the large fall between 7 a.m. on the 11th and 7 a.m. on the 12th indicated that it was moving westward on the southern or middle track (see fig. 4). The stratus blowing over the hilltop prevented any observation of the upper clouds.

At 10 a. m., however, the stratus broke up, and the following were the notes made:

Aug. 12, 1915. 10 a. m.

Ins.		
29.749	nne, 20 mis./hr.	2/10 Str., nne. 2/10 Fr-Cu., ne. 1/10 Ci. band, se. Thin cirrus veil over blue sky between clouds.

Now from the parallelogram of velocities (fig. 7) it was found that the cyclonic wind was 21 miles from the north, so that a was 270°, and so that

From the wind	$\beta=314°$
From the cumulus	$\beta=338°$
From the cirrus	$\beta=334°$
Mean	$\beta=329°$

The true value of β was 346°, so that the deduced direction of the center was fairly correct.

It will be noticed that the wind velocity was in accordance with the fall below mean, namely, 0.18. In fact, between 7 a. m. and 1 p. m., the observed wind was 15, and the cyclonic wind 17, which is in exact accordance with equation (4). But after 2 p. m. irregularity set in; the wind died down; sometimes there were puffs from the west; and all the time the barometer was steadily falling. The irregularity was due to a secondary in advance of the primary on its northwest edge; and nothing more could be made of the wind.[21]

The barometer was falling steadily, however, and might indicate whether the center was approaching Kempshot directly or not.

Let V be the velocity of the center in miles per hour, and G be the gradient in inches of mercury per mile; then the rate of fall per hour will clearly be GV, provided that the center is moving toward the place of observation.

But $G=\Delta p/2r$ from equation (2) supposing that $a=0$; and as the time of arrival is clearly r/v, provided again that the center is moving toward the place of observation, it follows that

$$\text{Time of arrival} = \frac{\text{Fall below mean}}{\text{Twice rate of fall}}. \qquad (6)$$

It is important to show that this equation requires no computation; the barometer readings must of course be reduced and corrected for diurnal variation, and then arranged as in the following table, where the difference of pressure between 7 p. m. and 9 p. m. is twice the fall per hour, and is set opposite 8 p. m., and the rest follows as a matter of course:

Date and hour.	Barometer.	Fall below mean.	Twice rate of fall.	Time of arrival.
	Inches.			
Aug. 12, 1915, 7 p. m.	29.673	0.26		
8 p. m.	.646	0.28	0.055	13th, 1 a. m.
9 p. m.	.618	0.31	0.055	2:30 a. m.
10 p. m.	.591	0.34	0.048	5 a. m.
11 p. m.	.570	0.36	0.031	11 a. m.
12 p. m.	.560	0.37		

The want of constancy in the last column clearly showed that the center was passing by Kempshot, either to the north or south of that place.

There is not much more of interest; rain squalls set in at 11 p. m. when the center was 113 miles away; after 1 a. m. on the 13th the heavy northwest rain squalls showed that the center was passing north of Kempshot; the lowest pressure was 29.286 inches at 5:25 a. m. with wind south, 40 to 60 miles an hour with the usual heavy squalls; and the nearest approach of the edge of the calm area was 25 miles.

[21] The confusion reached a climax at 7 p. m. when some lower cloud was moving fast from northeast, and when there were some cirrus bands also moving from northeast.

EXAMPLE 2.

August, 1916, Kempshot. *Mean barometer, 29.920 inches.*

10th, 7 a. m., 29.970
11th, 7 a. m., 30.053
12th, 7 a. m., 30.047 } Fine weather; usual winds and clouds.
13th, 7 a. m., 30.007 } On the 10th and 11th usual showers from cumuli.
13th, 3 p. m., 29.982
14th, 7 a. m., 29.921 Wind east 5 mis./hr.; 5/10 cir., se. Fine.
14th, 3 p. m., 29.897 Wind eastnortheast 3 mis./hr.; 10/10 cir.-st., se.[22] Great haze over the land.

The anemometer showed an average of 8 miles an hour between 7 a. m. and 3 p. m., and this was used to find the cyclonic wind which was 6 miles from the north, so that α was again 270°; and

From the wind..... $\beta=314°$
From the cirrus..... $\beta=334°$

Mean..... $\beta=324°$

while the true β from the subsequent chart was 343°.

15th, 7 a. m., 29.803 inches; wind light and variable, 5/10 A.-Cu., ne., 5/10 cirrus veil.
15th, 3 p. m., 29.721 inches; wind, ne., 20 mis./hr., 4/10 Fr.-Cu. ne., 6/10 St.-Cu., ne.

Consequently the cyclonic wind, $v=18\frac{1}{2}$, which is in almost exact agreement with equation (4); and $\alpha=248°$; while

From the wind..... $\beta=292°$
From the St.-Cu..... $\beta=338°$

Mean..... $\beta=315°$

and the true β was 322°.

At 6 p. m. the usual rain squalls set in, and equation (6) was applied; but as the center again was not directly approaching Kempshot, it will be convenient to apply equation (6) to Negril Point Lighthouse observations, with the following results:

Date and hour.	Barometer.	Fall below mean.	Twice rate of fall.	Time of arrival.
1916.	*Inches.*			
Aug. 15, 6 p. m.	29.641	0.28		
7 p. m.	.574	0.35	0.112	10 p. m.
8 p. m.	.529	0.39	0.196	10 p. m.
9 p. m.	.378	0.54	0.286	11 p. m.
10 p. m.	.243	0.68		

As a matter of fact the edge of the calm area arrived at 11 p. m. It passed centrally over Negril Point Lighthouse, and subsequently the wind rose to 96 miles, and even to 120 miles an hour for short intervals, as measured by the anemometer.

Returning to Kempshot: The lowest pressure was 29.19 inches; the wind was estimated at 60 miles an hour, and equation (4) gives 64. But the gusts were very heavy; the pressure plate showed a maximum of "30 pounds" per square foot; and if

$$v^2=280P, \tag{7}$$

then for the particular instruments at Kempshot, the maximum gust was 92 miles an hour, or half as much again as the average wind.

[22] Dense, and therefore to be taken as cirrus.

NOTES.

(A) *The gradient:*

Let Δp be the fall below mean at a point on the curve r miles from the central area; let $\Delta p'$ be the fall when r is increased by 1. Then if G be the gradient,

$$G=\Delta p-\Delta p'=\Delta p(1-\Delta p'/\Delta p),$$
$$=\Delta p\left\{1-\left(\frac{r-a}{r-a+1}\right)^{\frac{1}{2}}\right\},$$
$$=\Delta p\left\{1-1/\left(1+\frac{1}{r-a}\right)^{\frac{1}{2}}\right\},$$
$$=\Delta p/2(r-a), \text{ nearly.}$$

(B) *The tangent:*

Let Δp_0 be the fall at the center, let Δp_1 be the fall at the point where the tangent takes off, and let r_1 be the distance of this point from the central area. Then

$$G=\Delta p_1/2(r_1-a)=(\Delta p_0-\Delta p_1)/r_1,$$

therefore

$$r_1\Delta p_1=2(r_1-a)(\Delta p_0-\Delta p_1),$$

therefore

$$(r_1-a)\Delta p_1=2(r_1-a)(\Delta p_0-\Delta p_1-a\Delta p_1),$$

therefore

$$\Delta p_1=2(\Delta p_0-\Delta p_1)-a\Delta p_1/(r_1-a),$$
$$=2/3\Delta p_0-a\Delta p_1/(3[r_1-a]).$$

But from equation (1)

$$p_1^2=c^2/(r_1-a);$$

and eliminating (r_1-a),

$$\Delta p_1=2/3\Delta p_0-a\Delta p_1^3/3c^2.$$

(C) *The constant k:*

Let $t=0°$, so that $p=k\rho_0$, where ρ_0 is the density of the air at 0° corresponding to the pressure p. But if B_0 be the height of the barometer reduced to 0° at the place where the experiment was made to determine k, g be the force of gravity at that place, and σ_0 the density of mercury at 0°, then

$$p=g\sigma_0B_0=k\rho_0,$$

so that

$$k=g\frac{\sigma_0}{\rho_0}B_0.$$

And by taking feet and seconds as the units of space and time, and by weighing equal volumes of mercury and of air at pressure B_0, k was found equal to 843,663.

To reduce feet per second to miles per hour we must multiply by 15/22; but k must be multiplied by the square of this ratio, remembering that g is given in feet per second per second; and so we get $k=392{,}200$ in miles per hour.

(D) A few values of ϕ_2 and ϕ_3 were found for $\alpha=39°$, and 189°, so that we have the following:

β	ϕ_2	ϕ_3
343°	113°	199°
39°	105°	198°
189°	69°	189°

We notice failure for ϕ_2 when the center lies to the west. This is quite in accordance with the breaking up of the clouds, all but the highest, after a cyclone has passed; but while the center is more or less to the east, the direction of cumulus can be depended on as already stated, though preference should be given to cirrus.

THE SETTLEMENT OF TROPICAL AUSTRALIA.

By GRIFFITH TAYLOR, D. Sc., Physiographer.
(Commonwealth Meteorological Bureau, Melbourne, Australia).

[*Reprinted from* The Herald, Melbourne, Victoria, Oct. 27, 1917.][1]

The fundamental problem in Australia is the settlement of her empty tropical area. Opinions as to its economic value are most conflicting. A recent report stated that it is "undoubtedly the best and richest portion of the continent"; while I have just heard of a returned settler who declared that the only aspect of the Territory which pleased him was that which he saw from the stern of a southbound steamer! The truth, as usual, lies between.

It is on the whole fair pastoral country—which is very lightly stocked at present. It has limited areas of rich, agricultural land— which are practically untouched. In the hinterlands it has numerous mining fields, usually of medium grade—many of which have been abandoned owing to lack of labor. No serious student can doubt that natural resources of very considerable value are awaiting exploitation—but the great handicap, whether it be actual or only imagined, is certainly to be found in the climate.

In the following brief article I shall dwell chiefly on this aspect of the problem, more especially as it concerns the undeveloped areas in the Territory and West Australia.

A very cursory acquaintance with hygienic and economic problems leads one to the conclusion that the two climatic features which are most usually discussed—i. e., average temperature and annual rainfall—are of relatively minor importance.

As regards the human organism the factor of humidity is of greater importance than temperature. As regards plant life the season and reliability of the rain are at least as important as the total amount.

We can, with comparative ease, map Australia to show the rain reliability fairly accurately.

Suppose we consider the annual rainfall at Melbourne for a long period of years, and find the deviation from the normal in each year. We observe, of course, that in some cases the total annual rainfall is above the average (25 inches) at other times below this figure. If we take these deviations and average them, we find an average deviation of 12 per cent from the normal. Thus we may ordinarily expect fluctuations from 22 inches to 28 inches a year at Melbourne.

If now we apply the same test to the eastern portion of the Barkly Tableland—a valuable grazing area in the Northern Territory—we find that the reliability is much less and the average deviation is nearly 50 per cent (see the shaded areas in the map). Hence here the rainfall may be anything between 12 inches and 37 inches—although on the average it is much the same as at Melbourne.

So far as I know those optimists who propose to grow wheat in our tropical lands have given little attention to the season of the rain; and none at all to its reliability as discussed above! As I have shown elsewhere there are some regions where economic wheat growing may be possible in our hot lands—but they are neither in the Barkly Tableland nor in the south of the Territory.

Now let us turn our attention to another factor which is a potent control in tropical lands. It is generally accepted by physiologists that the best available instrument for testing the suitability of a region as regards habitability, is the wet-bulb thermometer.

[1] Communicated by the author.

Prof. Gregory has adopted 78°F. (wet-bulb) as an upward limit—"above which continuous hard work becomes impracticable." I do not agree with him altogether, for 78°F. (wet-bulb) is quite common along our northern coast—but this statement (by a strong supporter of tropical white settlement) will free the following deductions from a charge of exaggeration.

For reasons which I have elaborated elsewhere, I have adopted 70°F. (wet-bulb) as the limit of comfort for our race. This means that when the average wet-bulb remains above 70°F. day after day for a long period conditions are not favorable for close white settlement. An open-air, active occupation, such as stock-riding, has little to fear; but strenuous field labor, sedentary indoor life, and especially domestic work and the care of young children cannot (in my opinion) be carried on under favorable circumstances at present, with continuous high wet-bulb temperatures of this order.

Here I shall be met with numerous descriptions as to how "John Jones lived to 95 and never left the tropics"; how "Mrs. Jones raised five healthy children"; how that excellent clerk Brown "pines to return to the healthy life in the north", and so on and so forth.

These statements are all true—but they do not represent average conditions, nor are these sturdy pioneers (to whom be all honor) typical emigrants. Close settlement, unfortunately, depends on an influx of average settlers. There is nowhere in the world, so far as I am able to discover, a region resembling our northern coast lands with an important white settlement.

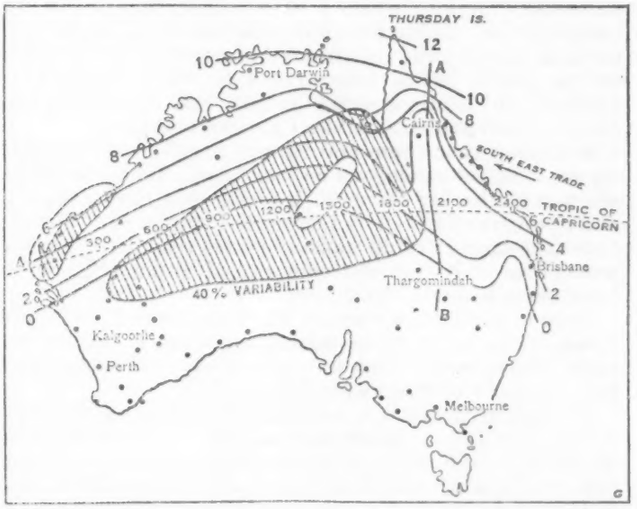

FIG. 1.—Important climatological boundaries for Australia. *A–B* separates the eastern fairly uniform rain region from the western winter-drought region. Shaded areas have very erratic rains (40 per cent variability). Lines connect points having the same number of months with an average wet-bulb temperature of 70° F., e. g., Thursday Island has 12 months, Brisbane has 2 months of that condition.
Approximate scale of miles is indicated on the Tropic of Capricorn.

In the map (fig. 1) I indicate approximately how this question of wet-bulb temperatures affects close settlement in our tropics. Many of my readers have anathematized those oppressive days in February which are so disagreeable a feature of Sydney (and indeed in much less degree are not unknown in Melbourne).

Yet Sydney has no month approaching an average of 70° (wet-bulb). Brisbane has two such disagreeable months, and conditions become continuously less attractive as we travel up the coast. At Mackay such high wet-bulb temperatures obtain for 6 months in the year, at Cooktown for 10, and at Thursday Island all the year round.

Probably one or two disagreeable months in the year have no particular effect on the well-being of the settler—but let us follow the 6-months isopleth on the map. It runs along the Queensland coast north of Mackay, sweeps to the north of the Atherton Tableland (that most promising region in our tropics!); along the Gulf coast, through Daly Waters, and along to Roeburne, W. A.

This line is no fanciful creation but is a definite climatological boundary. Yet I should point out that the unfavorable zone thus marked out is not all of one type. Another factor comes in which, luckily, greatly ameliorates conditions on the Queensland coast. Here blow the steadiest onshore winds in the world—the Southeast Trades. A high wet-bulb temperature, if accompanied by a fresh breeze, is robbed of half its terrors. Unfortunately the effect of local winds on health and comfort has not been investigated in our tropics, and my own experience is limited to the Queensland coast.

Having shown that the 6-months isopleth on the map has a real climatological value, what bearing has it on the settlement of our tropics? It will be noticed that it is precisely the low-lying river alluvials which are adversely affected. Here irrigation may ultimately be possible, for there are many truly fine rivers running into our northern seas. But I doubt if a white farming community will settle in these suitable areas for very many years, and this brings me to the last section of this article.

I have found it a comparatively simple matter (by means of diagrams which I have called climographs) to compare very closely the climatological conditions in our tropical towns with conditions obtaining in other parts of the world. Thus Darwin has the same climate as Cuttack, in India; Broome is like the mouth of the Congo; Townsville resembles Calcutta closely.[2]

Assuming that these and similar parallels are correct, we see that the analogous regions (homoclimes) for Darwin are settled by Siamese, Indians, and Bantu blacks, and in northern Brazil by half-caste Portuguese. Wyndham (the hottest of all moist climates recorded), has for homoclime only the extreme tip of India. Broome's homoclime is settled by Bantu.

Only in the inland country like that around Tennant's Creek, have we a homoclime even sparsely settled by north Europeans. This is the recently conquered German territory of Southwest Africa.

In eastern Brazil is a most interesting series of settlements; but the Germans have settled in the homoclime of Grafton; the Italians in Brazilian "Brisbane," and only the Spanish emigrants touch even the coolest tropical regions.

We learn, therefore, from our brief but comprehensive climatological study that Australia is ahead in tropical settlement as in other sociological experiments. Her white sugar growers around Cairns and Mourilyan are the advance guard of the white farmer in the Tropics.

I have no space to do more than mention one great asset in our northern lands—their remarkable freedom from such scourges as yellow fever, beri-beri and malaria. There seems good reason to hope that even the latter will soon be almost stamped out.

What then is indicated as regards the immediate future of our empty northern lands? I have no novel suggestions to make. The country is a pastoral one—it is not, in my opinion, an agricultural region. Quite apart from questions of labor and market I do not think that the north coast agricultural areas are suitable for white labor at present.

I have several times in this article hinted that conditions may be more favorable in the future. In four or five generations there is reason to believe that our native born will become thoroughly acclimatized in the subtropical areas, and will gradually expand into hotter and more humid zones to the north.

Until that time arrives let us develop the pastoral industries. Let us build railways, dig wells, and sink artesian bores. Let us strengthen our naval and aerial fleets. Let us, above all, have scientific direction and a definite aim. It is the lack of these which has ever hindered British enterprise, while they have made the Germans a world-shaking power. Fas est et ab hoste doceri.

[2] *See* Commonwealth Bureau of Meteorology Bulletin No. 14: Control of settlement by humidity and temperature . . . by *Griffith Taylor*. Melbourne, September, 1916. 32 p. 21 figs. 4°.—C. A., jr.

PRACTICAL HINT IN FORECASTING MINIMUM TEMPERATURES.

By WILLIAM G. REED, Meteorologist.[1]

[Dated: Pomona, Cal., Dec. 16, 1917.]

Referring to the use of the Smith-Donnel method of estimating the probable minimum temperature (this REVIEW, August, 1917, pp. 405 ffg.), I have tried the straight-line equation for the conditions at Pomona, Cal., and while the values of a and b were determined from insufficient data yet the method seems applicable to this locality. While a and b are most conveniently computed by Professor Smith's form of the equation (see 3, below) I suggest that in practical use the hygrometric formula be expressed as follows:

$$t_n = t_d + (a + br), \tag{1}$$

where t_n is the minimum temperature next morning, t_d is the evening dewpoint, r is the relative humidity, and a, b, are constants to be determined. Mathematically this expression is identical with

$$t_n - t_d = a + br, \tag{2}$$

which Prof. Smith has written (loc. cit., equation 1) as

$$Y = a + bR, \tag{3}$$

The advantages of the form of (1) are that the quantity sought is the only term on the left-hand side of the equation; the possible doubt as to the sign of Y, or $t_n - t_d$, is removed; and the equation represents directly what it actually is to the forecaster, viz, a means of modifying or correcting the current dewpoint so that it shall become the minimum temperature of the next morning. While there should be no doubt as to the sign of Y, in practice I have found that I have hesitated in writing the quantity, between $t_n - t_d$ and $t_d - t_n$. I believe that any change in the statement of the formula, which will make the mechanical operation automatic will be an advantage in practice.

The form of the statement by Prof. Smith is better for the study of the relationship and the theoretical development of the method; the form here suggested is intended only to minimize the chance of errors in the practical application of the relationship in actual forecasting.

[1] Conducting Weather Bureau investigations into protection against frost.

METEOROLOGY AND WAR-FLYING.[1]

Three lectures given at the United States Army School of Military Aeronautics, Massachusetts Institute of Technology.

By Prof. ROBERT DECOURCY WARD.

[Dated: Harvard University, Cambridge, Mass., Dec. 29, 1917.]

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INTRODUCTION.

There is no need of emphasizing the importance of a knowledge of meteorology on the part of those whose business it is to sail through the ocean of air. This ocean has its tides, its currents, its waves. It is beginning to be charted, but only just beginning.[2] A seaman navigates his vessel in all sorts of weather, but skill in local weather forecasting, and a practical knowledge of the laws of storms, are invaluable in making possible a speedier, safer, and more successful voyage. Similarly, the navigator of the air, though war service often involves flying under atmospheric conditions far from favorable, inevitably finds, sooner or later, that the more he knows about the air which he is navigating, the better equipped he is as a fighter, as a photographer, or on reconnaissance work. At critical times, meteorological knowledge has time and again proved its practical value to those who navigate the air. Meteorologists are waiting to put all that they know at the service of the men who fly. And the men who fly will, in their turn, advance meteorological science by means of the facts which their own practical experience in the air will impress upon their minds. He who knows most about practical meteorology is the best equipped for service in the air. He is, therefore, the most likely, other things being equal, to do his country the greatest service.

The aviator who is sent to a foreign war zone may wisely, if time allows, inform himself regarding the climate of the region in which he is to fly. It is a practical help to know about the prevailing winds, the number of stormy days, the distribution and amount of precipitation, the occurrence of gales, the general character of the weather, and the like. Such data are easily obtainable from the usual climatic summaries.[3] A convenient recent summary of French data is printed in the MONTHLY WEATHER REVIEW, October, 1917, pp. 487–496, and reprinted in the November or December, 1917, issues of the monthly "Climatological data" issued at section centers.

Climate is the average, and is made up of the individual, day-by-day atmospheric conditions which we call weather. A climatic summary for any given month, or season, shows the *average* or *normal* conditions. It by no means necessarily shows what any particular month or season is to be. There is no way, as yet, of knowing that in advance. Obviously, some knowledge of the weather which he is to experience to-day and to-morrow, is of immediate and essential importance to the aviator. He is helped by knowing something of the general climatic conditions of his field of operations. But he wants, much more, to know what weather to expect within the next few hours. In other words, he wants to know "not what *may* be but what *will* be."[4] He needs regular daily weather forecasts. And these require an organized system of meteorological observations made by trained observers, collected by telegraph, and charted. With such an organized military meteorological field service the aviator is not himself directly concerned. The forecasts are supplied to him. He can, however, help himself a great deal if he has a good "working" knowledge of daily weather maps[5]; if he knows something of the relations and movements of weather types, and is sufficiently familiar with weather prognostics to be able to make his own rough-and-ready forecasts in case he can not receive the official forecast, or wishes to interpolate his own prediction at a time when no regular forecast is issued.

Details regarding the field weather service of the Allies are confidential, but information which has been given to the public shows that the meteorological organization is widespread and effective. So far as Great Britain is concerned, we know that a separate unit of the Royal Engineers has been created for meteorological service in the field. The service in France has been under the command of Maj. Ernest Gold, and that in the eastern Mediterranean under Capt. E. M. Wedderburn. With him is, or was, Lieut. E. Kidson, of New Zealand, who has distinguished himself as magnetician in the service of the Carnegie Institution of Washington. Maj. H. G. Lyons, R. E., formerly director general of the Egyptian Survey Department, took charge of the Mediterranean area in May, 1915. A professor of meteorology to the Royal Flying Corps has been appointed, the appointee being Lieut. (now Maj.) G. I. Taylor, Royal Flying Corps, who was previously Schuster Reader in Meteorology. The special meteorological service organized by the Italian Army has published several bulletins dealing with the military relations of meteorology and climatology. Among the subjects so far considered are the climates of the districts in the war zone and details regarding avalanches, with lists of places specially subject to them.

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[1] GENERAL REFERENCES.

Great Britain. Royal Flying Corps. Training manual.

Shaw, Sir Napier. The weather map. Meteorological Office, London, 1917. 3d issue. (M. O. no. 225l.)

In addition to these sources of information and other references given later, the following publications may prove useful:

Linke, Franz. Aeronautische Meteorologie, Pt. I and II. Frankfurt a/M., 1911. 133 and 126 p. 8°. (Deals chiefly with balloons and is somewhat out of date, but still useful.)

Humphreys, W. J. Physics of the Atmosphere. Jour. Franklin Instit., March, 1913. Specially pp. 228–241.

McAdie, Alex. G. Principles of Aerography. Chicago, 1917. 8°. (The most recent book on the subject; summarizes the latest advances in meteorology, lays special emphasis on modern methods of dealing with the problems of the atmosphere and on the practical application of the aerologist's knowledge.)

Idem. Aviation and aerography. Aviat. and aeronaut. engin., Aug. 15, 1916, 1: 8–11; also in Sci. amer. suppl., June 2, 1917, No. 2161, pp. 341–342.

Idem. Aerography: the science of the structure of the atmosphere. Geogr. rev., New York, April, 1916, 1: 265–275.

Rotch, A. Lawrence. Conquest of the air. New York, 1909. 8°.

Sounding the ocean of air. 1909. 174 p. sm.8°.

[2] *Rotch, A. Lawrence, & Palmer, Andrew H.* Charts of the atmosphere for aeronauts and aviators. New York, 1911.

[This is a pioneer publication on its subject. It presents, in a practical form, some of the results obtained at Blue Hill Observatory, Mass., during 20 years of observation. The charts are "the first of their kind adapted to the use of airmen". They relate chiefly to Blue Hill, but apply also to larger portions of the United States. The final chart shows the best aerial routes across the North Atlantic Ocean in summer.]

[3] The standard book on climate is *J. von Hann:* Handbuch der Klimatologie. 3d ed., Stuttgart, 1908–1911. 3 v. 8°.

On the western front the winds are prevailingly from the western quarter. Hence the German machines have an advantage in case of engine trouble. An Allied airplane will be likely to have "its gliding path so shortened that the aviator will mostly have to land in 'No Man's Land' if he does not come down within the enemy lines." F. W. Lanchester, the "London Times" correspondent on the western front, reports that "fighting nearly always drifts over the enemy's territory, and that the Germans habitually endeavor to draw our men farther over their own ground, where even a small mishap may prevent them, against the adverse winds, from regaining their own lines."

[4] Sir Napier Shaw.

[5] See section on *Weather Forecasting* p. 599, below.

The United States Signal Corps, with the cooperation of the Weather Bureau through the National Research Council, has also organized an extensive meteorological service in France. Maj. (formerly Supervising Forecaster) E. H. Bowie has charge of the forecasting, and has associated with him Lieut. R. H. Weightman. Maj. (formerly Prof.) Wm. R. Blair has charge of the field observations, specially the aerological observations with pilot and sounding balloons for the benefit of aviators and artillerists. He will have associated with him Capts. A. H. Thiessen and W. G. Reed, and a considerable number of other Weather Bureau employees who are now attached to this important military unit. A somewhat similar service, in the interest of naval meteorology, is being organized by Senior Lieut. W. F. Reed, jr., U. S. N., with whom likewise are associated a number of Weather Bureau men, forming a nucleus for the development of a more extended service of a meteorological nature.

THE ATMOSPHERE.

General.

With the composition of the atmosphere in which he flies, the aviator has no particular concern. He may be interested in the nitrogen as a source of nitric acid and of nitrates, the chemical constituents of gunpowder and of fertilizers. The water vapor becomes critical when condensed into clouds or rain. The oxygen plays an important part in engine performance, but its amount becomes of direct concern to the pilot only when, at great altitudes, insufficient oxygenation of the blood may lead to temporary physiological disturbances. It is the physical conditions of the atmosphere, notably temperature, pressure, air movement, which are of immediate interest in aviation.

Temperatures in the free air.[6]

In the average, the temperature of the free air falls with height. The mean rate of decrease is 1°F. in 300 feet of ascent (10°F. [5.56° C.] per km.). Therefore, if the temperature at sealevel happened to be 50°F., the freezing point (32°F.) might be expected at about 1 mile above the surface.[7] At a height of about 5 miles, the freezing point of mercury (−40°F.) is reached.[8] Temperatures between 0° and −40°F., varying with the season and with the weather type, may be expected at the present highest flying levels. There is a seasonal difference of temperature between summer and winter in the free air, but it is less than at the earth's surface. At about 6 miles the mean winter temperature is in the vicinity of −70°F. (−56.67°C.), and that of summer, −60°F. (−51.11°C.). This decrease in temperature continues up to the level of the highest clouds (about 6 miles = 10 kms.), beyond which, so far as observations have extended, there seems to be no further decrease of temperature with height. There may even be a slight increase. This upper layer (*stratosphere*) is beyond flying limits. The lower layer (*troposphere*) is the one with which we are concerned.

Near the earth's surface (i. e., within 2 miles or so), the rate of change of temperature vertically is very irregular. It may be more, or less, rapid that 1° F. in 300 feet; there may be no change, or there may even be a rise of temperature with height. On calm, clear nights, in the colder months especially, it very often happens that the temperature distinctly rises for a time with increasing elevation. There is then a warmer layer of air over a colder one. This condition is known as an "inversion of temperature." It is associated with cool or cold, more or less stagnant lower air; is often accompanied by a fog, and quickly disappears if a wind springs up, or when the morning sun is strong enough to warm the earth's surface and the lower air. When flying up through such an "inversion," the aviator will find the temperature rising at first, and then falling at something like the usual rate. Above the stagnant lower air, also, the machine will enter moving currents. Inversions are not limited to the earth's surface. They are frequently found aloft, especially above cloud layers. The kind and amount of change of temperature vertically is an indication of atmospheric stability or instability. When the temperature decreases rapidly with increasing altitude, the air is unstable, and vertical currents will occur. When the temperature increases with ascent, the air is stable, and there is little vertical movement as far up as the inversion extends. In flying through successive layers of air, many different temperature conditions may be met with, but on the average, as stated above, the temperature falls at a rate of 1° in 300 feet.

Pressure.

For several reasons, pressure is the most important meteorological element in aviation. (1) Observations of pressure make the determination of altitude possible; (2) the resistance of the air and the performance of the engine to some extent depend on pressure;[9] (3) pressure and its changes control air movements and, through these, the other weather elements, such as temperature, humidity, cloudiness, rainfall. The ocean of air and the ocean of water are alike in many ways. The deeper the diver descends below the surface of the water, the greater the pressure he has to endure. The deeper man is submerged in the atmosphere, i. e., the more air there is over him, the greater the weight or pressure of that air. The decrease of pressure aloft, with decreasing depth of immersion in the ocean of air, may produce certain physiological effects which may, usually temporarily, cause discomfort or perhaps even disability.[10] Air, like water, adjusts itself to differences of level; "seeks its own level." Moving air (wind) is making such an adjustment. Atmospheric pressure over the higher latitudes of the earth's surface usually changes considerably

[6] Information regarding the methods of obtaining temperatures in the free air may be found in the newer text books on meteorology.

[7] 50° − 32° = 18°: 300 × 18 = 5,400 feet.

[8] Many hundreds of observations in central Europe, made with balloons-sondes and manned balloons, have given the following mean temperatures at various altitudes in the free air, up to the present highest flying levels:

Altitude.		Temperature.	
Miles.	*Kms.*	°*F.*	°*C.*
(0.0)	(0)	(48.9)	(9.39)
0.6	1	41.0	5.00
1.2	2	32.9	0.50
1.9	3	24.8	− 4.00
2.5	4	15.4	− 9.22
3.1	5	4.3	−15.39
3.7	6	− 7.6	−22.00
4.3	7	−20.2	−29.00
5.0	8	−33.2	−36.22

In converting statute miles into kilometers, and kilometers into statute miles, the following simple rules, which give results sufficiently accurate for all ordinary purposes and were suggested by Prof. J. B. Woodworth, of Harvard University, will be found useful.

A. To convert statute miles into kilometers:
To the number of miles add $\frac{1}{2}$, $\frac{1}{10}$, and $\frac{1}{10}$ of that number.

B. To convert kilometers into statute miles:
To $\frac{5}{8}$ of the number of kilometers, add $\frac{3}{8}$ of that number. If, for every 1,000 miles, 4 be subtracted from the final result, still greater accuracy is secured.

[9] The power of the engine depends on the amount of air, and on the corresponding amount of fuel, taken into the cylinders at each explosion i. e., on the density of the air. This is dependent on the pressure and also on the temperature. Under ordinary conditions when the pressure is higher, or the temperature lower, the performance of the engine is better. When the pressure is lower, or the temperature higher, the tendency is the opposite. On a hot day the performance near the surface would be somewhat like that at a higher altitude on a normal day. When the sealevel pressure is low, the engine works under conditions similar to those somewhat above the surface on a day with normal pressure. There is, however, compensation for the decrease in the power of the engine at great altitudes in the lessened resistance of the air when the density is lessened. And there comes in also the effect of the cold at great altitudes in causing poor ignition.

[10] Information on this subject may be found in numerous writings on mountain climbing and on aeronautics; also in medical works. See further *J. Hann:* Handbook of climatology, v. 1, 2d ed., translated by *R. De C. Ward*, New York, 1903. pp. 224-230.

from day to day. In the construction of weather maps for the purposes of weather forecasting, the meteorologist must know the pressure conditions over a large area. In flying, it is the pressure which gives the aviator his altitude.

The mercurial barometer is the standard instrument for determining pressure in all accurate meteorological work. It is, however, wholly unsuited for use in flying. It is heavy, difficult to carry, very delicate, and its readings require many corrections.[11] The height of its mercury column (in inches or millimeters) indicates the pressure of the air. The aneroid ("without fluid") barometer is portable, is not so easily broken, and does not require so many complicated corrections. Hence it is a much more convenient instrument, but is less accurate. An increase in pressure compresses the corrugated top of an elastic metallic vacuum box, and a decrease in pressure allows the box to recover again.[12] A spring helps the action, and a simple system of arms and levers magnifies and changes the vertical movements of the box cover into a circular movement of a needle around a dial. This dial is graduated into inches and tenths of inches, or into millimeters, by comparison with a standard mercurial barometer. Aneroids should frequently be compared with mercurial barometers in order to insure the greatest possible accuracy. They are more reliable in showing changes of pressure than absolute pressures. They need careful handling; should if possible be kept from extreme and sudden temperature changes and from all violent knocks or jars. As the mechanism lags behind the pressure-change because of unavoidable defects of elasticity, it follows that during a rapid ascent the readings are likely to be too high, and during a rapid descent they are likely to be too low. This would give too low an altitude in ascending and too high an altitude in descending. It is obvious that this lag should be absolutely the minimum obtainable.

Aneroids may be made self-recording, and are then known as barographs.[13] The changes in pressure are recorded on a sheet of paper wound around a cylinder driven by clockwork inside. Barographs are made of various sizes, even down to those which are small enough to be carried in the pocket.

It is in the determination of altitudes that barometers have their chief use in aviation. If the difference in pressure between two places, one higher than the other, be known, the difference in the elevation of the two stations may be determined. The pressure at the higher station will be less because there is less weight of air upon the barometer there. Between the two stations there is a column of air whose height corresponds to the difference in pressure at these stations. If the height of this column be known, the elevation of the upper station above the lower is known. Unfortunately for easy memorizing, the heights of the air columns corresponding to given pressure-differences vary, depending upon the density of the air, upon the temperature, pressure, humidity, etc. Formulæ are available for use in determining the differences of height where the various required elements are known. Published tables, however, make the solution of the problem much simpler, and are widely used.[14] When aneroid barometers are provided with a scale to show altitudes as well as pressures, a certain length of air column, at a selected mean temperature and mean pressure, is taken as the standard. In other words, it is *assumed* that for a pressure change of, say, 1 inch, or 25 mm., the corresponding height of air column is so many feet, or meters. Clearly, whenever the pressure or temperature, or both, at the time of any observation differ from the selected mean, there will be an error in the resulting altitude as indicated on the altitude scale. This error may amount to several per cent. The aviator, however, does not have to know his altitude with absolute exactness. In the newest aneroids the errors are being gradually reduced.

For ordinary use in aviation, the "altimeter" replaces the aneroid barometer. The "altimeter" is an aneroid graduated to show height instead of pressure. It should be sensitive, and have an open scale, easily read. A good "altimeter," if properly adjusted, is sufficiently accurate for all ordinary flying purposes. No determination of altitude, it may be worth noting here, can be really accurate unless there are two *simultaneous* readings of pressure, one at the lower station, whose altitude above sealevel is known, and the other at the upper station, or in an aeroplane. In addition, the temperature of the intervening air column should be known. This is usually taken to be the mean of the temperatures at the upper and lower stations, observed simultaneously. The altitude of an aeroplane as indicated by aneroid, depends on the difference of pressure between the height at which the machine happens to be and the pressure at which it left the ground. As the surface pressures may very likely vary during a flight, it is easy to see that the supposed altitude of the machine may differ appreciably from its actual altitude provided these pressure changes have been considerable. This error can not be provided for under ordinary conditions of war flying. If the instrument be carefully adjusted to the pressure and altitude at the starting point, the readings may be assumed to be substantially accurate.[15]

In addition to the direct use of barometers in the determination of altitude, they are also important to the aviator in showing the distribution of pressure over the earth's surface. It is this which determines wind movement. When barometer readings are reduced to sealevel, and plotted on a map, differences of pressure are seen to exist. Places that have the same (sealevel) pressure are joined by lines known as *isobars* (equal pressure). Isobars are essentially like the contour lines on a topographic map. On the daily weather maps of the United States and Canada isobars are drawn for every 0.10 inch.[16] Any weather map [17] shows the existence of regions where the pressures are relatively low. These areas are surrounded by more or less circular or oval isobars; are marked LOW, and are depressions in the atmospheric topography. There are other areas of relatively high pressure; also more or less circular or oval in shape, and marked HIGH. These are elevations in the topography of the atmosphere. A weather map is to be regarded essentially as a contour map. It shows elevations and depressions; hills and hollows. If there were no disturbing causes, the pressure at sealevel would everywhere be the same; the atmosphere would be at rest.

[11] For information see *Charles F. Marvin:* Barometers and the measurement of atmospheric pressure. Circular F, Instrument Division, U. S. Weather Bureau.

[12] Several vacuum boxes may be used.

[13] *See* "Barometers and the Measurement of Atmospheric Pressure."

[14] See e. g., Smithsonian Meteorological Tables, or "Barometers and the Measurement of Atmospheric Pressure."

[15] In case the "altimeter" becomes broken, and an ordinary aneroid, graduated only for pressures, is available, it may be of help in an emergency to know that about 1000 feet of altitude roughly correspond to about 1 inch of pressure-decrease. This is a very crude and therefore inaccurate means of judging heights, but it may serve for lack of something better.

[16] On the English maps isobars are drawn for intervals of 5 mbars. (millibars). One thousand millibars equal 1 bar. The bar is equal to the pressure of 29.531 inches (750.1 mms.) of mercury at 32° F. (0° C.) and at latitude 45°. It is equivalent to a pressure of 1 megadyne per square centimeter, i. e., to 1,000,000 dynes *per square centimeter. Hence a millibar is equivalent to 1,000 dynes per square centimeter.*

[17] See later section on *Weather Forecasting*, p. 599.

A glance at any weather map will show that the distances between the isobars vary. As the pressure difference between any two adjacent isobars is always the same (0.10 inch or 5 mbars.), it follows that where the isobars are close together the pressure is observed to rise or fall rapidly as one crosses them, and where they are far apart the rise or fall is slow.[18] The *barometric* or *pressure gradient* is steep or gentle; strong or weak. In other words, just as crowded contour lines show steeper slopes on a topographic map, so crowded isobars on a weather map show steeper slopes of the isobaric surfaces in the atmosphere. And as water on the earth's surface flows down hill slopes and into hollows, so air, obeying a similar impulse, tends to flow away from areas of higher pressure and toward areas of lower pressure. If left to itself, the wind would naturally blow directly down the atmospheric slopes along the shortest path from one isobar across to the next lower isobar, and so on until it reached the bottom of the slope (LOW). It would follow the line of most rapid pressure decrease, crossing the successive isobars at right angles. The winds would therefore blow directly out and away from centers of higher pressure, and directly into centers of lower pressure. They would be radial.

The wind in relation to pressures at the earth's surface.

The winds are unable to follow the line of the pressure gradient. The fact that the earth rotates causes winds in the Northern Hemisphere to be deflected to the right of a direct path, i. e., the tendency is for them to blow parallel with the isobars rather than directly across them.[19] Friction comes into play and resists the tendency of the wind to blow more and more to the right. The differences of pressure produce the slope (gradient) on which the air moves. The rotation of the earth deflects the wind (to the right in the Northern Hemisphere). Friction opposes varying resistances. The resultant surface wind directions are neither directly down the slope, nor parallel with the isobars, but somewhere between the two. Around an area of low pressure in the Northern Hemisphere the wind therefore blows in and around to the left. The system is an inward spiral, counter-clockwise, and is known as a *cyclonic* wind system. In the case of a similarly situated high-pressure area the winds blow out, and around to the right. This is an outward clockwise spiral—an *anticyclonic* wind system.[20]

So well defined are these systems of winds that one of the best-known laws of meteorology has been based upon them. *Stand with your back to the wind (in the Northern Hemisphere) and the pressure will be lower on your left hand than on your right.* This is Buys-Ballot's Law, and its formulation dates from 1857. It is a necessary consequence of the earth's rotation. Naturally, irregularities of pressure distribution, the varying effects of topography, and other causes, often cause local winds to depart from the general rule. If the minuter details of pressure could be observed and charted, most of the apparent "exceptions" would probably be seen to be in agreement with the rule.

[18] It seems better to reserve the expression "pressure change" for the change in pressure at one and the same point within a stated interval of time, e. g., "the 24-hours pressure change." United States forecasters map the 24- and 12-hour pressure changes and use them constantly in forecasting.—C. A., jr.

[19] *Ferrel's Law:* The amount of deflection depends upon the velocity of the wind and upon the latitude.

[20] These whirls develop centrifugal components which come into play in modifying the wind directions and velocities. In the case of a LOW, the effect of the gradient is balanced against the effects due to the earth's rotation and the centrifugal component of the whirl. In a HIGH, the gradient and the centrifugal component of the whirl are balanced against the earth's rotation.

Regarding wind velocity, it is easily inferred from what has been said above that where the isobars on a weather map are close together, there the winds will have higher velocities, and where the isobars are far apart, there the winds will be gentle. For surface winds, which are greatly affected by friction, no satisfactory definite rule can be given for a relation between wind velocity and pressure gradient. At moderate altitudes, however, it is possible, within certain limitations, to calculate both the direction and the velocity of the air currents.[21] One thing is very clear. Very small pressure differences can produce high winds.

Wind velocity may be estimated, and then expressed according to an accepted scale, such as the well-known Beaufort Scale dating from the early part of the last century. The equivalents of the numbers of the Beaufort Scale, in miles an hour and in pressure per square foot, have been determined.[22] On American weather maps, wind velocity is given in miles an hour in the printed table. On English maps, the number of barbs on the wind arrows indicate the velocity according to the Beaufort Scale. On the French maps the barbs indicate the velocity according to a scale of 4, but the tabulated observations use a scale of 9.

In the United States meteorologists commonly measure wind velocity by means of the Robinson cup anemometer.[23] This instrument is unsatisfactory for aviation purposes because it does not indicate the gustiness of the wind, which is usually much more important than mean velocity. A better instrument for this purpose is the Dines pressure-tube anemometer, much used in England. In this the varying wind pressure and suction raise or lower a float whose changes of level are recorded on a chart wrapped around a drum driven by clockwork.[24]

Even the steadiest wind is gusty. Observations with self-recording anemometers of the Dines and other patterns, show that gustiness varies greatly with different wind directions and in different places.[25] The Dines anemometer may also be adapted to show wind direction by providing it with a wind vane.

In war flying aviators have no occasion to make their own instrumental observations of any weather element. Such data are supplied by the military field weather services. It is, however, desirable that each aviator should have some knowledge of the essential meteorological instruments, so that if necessary he may read them himself.

AIR CURRENTS ABOVE THE SURFACE IN RELATION TO AVIATION.

There are no "holes" in the air. The term is misleading and inaccurate. It conveys the idea of a vacuum or of a partial vacuum; of a local deficiency of air which does not exist. The idea of "holes," of "pockets," and of "dead spaces" comes from the fact that there are often sudden changes in the relation of the aeroplane to the air current by which it happens, at the moment, to be supported. Such a failure in adjustment may be caused by a sudden change in the direction or in the velocity of the general currents in which the machine is flying, by encountering ascending or descending air movements, by flying across atmospheric waves, and in other ways. Horizontal gusts and lulls produce a temporary change

[21] See later under *Forecasts of Wind Direction and Velocity Aloft*, p. 599.

[22] See e. g., *W. N. Shaw:* Forecasting weather. London, 1911. pp. 30-31.

[23] See Instructions for the installation and maintenance of wind measuring and recording apparatus, Circular D, Instrument Division, U. S. Weather Bureau.

[24] A description of this instrument will be found in the Observer's Handbook of the British Meteorological Office.

[25] The *fluctuation of the wind* is the difference between the average maximum velocity reached in the gusts and the average minimum velocity in the lulls. The ratio of the fluctuation to the mean velocity is the *gustiness*.

in the pressure of the air against the machine—i. e., in the velocity of the aeroplane *through the air*, causing a momentary change in the lift. The resulting effects depend on whether the aeroplane is moving with or against the wind and on its relative velocity with respect to this wind. If the machine happens to fall rapidly, there is apparently a "hole." Again, when the angle at which the wind strikes the machine changes, there is also a change in the lifting power. If the angle becomes more upward, the machine will rise; if more downward, it will fall. Should a machine suddenly come into a current of air having exactly the same direction and velocity as itself, it would be in a "dead space." Under conditions of active vertical air movements an aviator may pass rapidly from an ascending to a descending current. His machine will then descend. A descending movement does not, however, continue until it strikes the ground vertically. It must obviously become more and more horizontal as it nears the surface. Again, a pilot may find his machine just on the dividing line between an ascending and a descending current. In such a situation there will inevitably be tips and bumps. Various combinations of such conditions as those here suggested explain "holes" and "pockets" and "bumps." [26]

A. General air movements essentially horizontal.

Layers.—The atmosphere, in spite of its being well mixed vertically, has more or less of a layer structure (stratification). Records of self-recording instruments sent up with ballons-sondes, and the courses of these ballons-sondes and of pilot balloons [27] have shown that these layers often differ considerably from one another in direction of movement; in velocity of movement; in temperature; in humidity; in cloudiness. Extended cloud sheets, for example, are often found in damp layers which have been cooled to their dewpoint, while above and below the sky may be cloudless. The rates of change of temperature vertically often vary a good deal in different air strata. It is when these rates are averaged that the rate of decrease of temperature of 1°F. in 300 feet, referred to in an earlier paragraph, is obtained. In flying, aviators thus often pass from one layer to another whose direction, or velocity, or both, may be different. A change in the adjustment of the machine becomes necessary. The machine may rise; it may fall slowly or rapidly as conditions may determine. Endless combinations are conceivable. No set rules can be given. Nor can the weather forecaster, from the daily weather map, tell definitely what the conditions of atmospheric stratification will be. Cloud observations help. Pilot balloons, when such are available, furnish the best means of determining the direction and the velocity of the higher air currents. Adjacent strata differing so greatly and so suddenly in direction and velocity from one another as to be dangerous, are rare. There is usually a gradual transition. Hence, if a strong current of air from one direction is above or below a strong current from an opposite direction, there is likely to be a layer of *comparatively* quiet air between. If difficulty is being experienced in any given layer, it should be remembered that the stratification is essentially horizontal, and a change of altitude will very likely bring better flying conditions. The maximum diversity between adjacent air strata occurs in connection with stormy weather, or when the weather is changing from fair to stormy.

Waves.—Friction between atmospheric strata moving over and differing from one another in density, direction, velocity, etc., often produces waves along the contact surface. These are essentially similar to the waves produced on water by wind. Balloons, traveling in such a wave layer, rise and fall with the waves. Von Helmholtz (1889) showed that atmospheric waves may have a length of hundreds of meters. When the moisture conditions are favorable, clouds form along the crests of these waves, while the troughs are unclouded or have thinner clouds in them. Under these circumstances, long parallel lines or rows of cloud are seen stretching across the sky. Sometimes these waves are only faintly developed, or appear in different parts of the sky. The lines of cloud may be continuous, or may be formed of separate small clouds, arranged in rows. The latter indicate a crossing of the layers, and the condition is similar to that of a "choppy sea," when long rollers are broken up into shorter and less regular waves by a change in the wind direction. Often a sheet of cloud is thrown into waves, the sky being wholly overcast, but the separate waves being distinguishable. Waves may occur at many altitudes. That atmospheric waves are often present when there are no clouds to indicate them is evident from the experience of aeronauts and of aviators, and from the records of delicate self-registering barometers, which at times show the passage, over the instruments, of regularly recurring oscillations of pressure. Flying along a wave level is apt to be "bumpy". If the machine is progressing against the waves, the irregularity of motion is greatest on account of the rapid changes in vertical motion. On the other hand, if the machine is flying with the wave motion, a smaller number of ascents and descents is experienced in the same interval of time. As the wave layer is an essentially horizontal stratum, relief can be secured by driving the machine up or down into a less disturbed region.

B. Local convectional currents, essentially vertical due to thermal controls.

Ascending currents are common on fine warm days, especially in summer. They are caused by the heating of the earth's surface under sunshine. The warmed air, being light, rises, as a cork rises through water. These rising currents are most common over mountains and hills, up whose slopes there are usually active ascending air movements during the warmer hours of fine summer days, and over open unforested areas. A freshly plowed field, of dark soil, is likely to be better warmed, and hence to be the seat of greater activity of ascending currents, than a field covered with crops or grass. When the warmed air rises high enough, and reaches its dewpoint temperature, the familiar fine-weather clouds of summer are formed, with their flat bases and bulging, convex tops (cumulus). These clouds are in many respects the most interesting from an aviator's point of view. They are "the visible tops of invisible ascending columns of air." As seen from above, "Cumulus clouds give the appearance of a very wild and rocky country; large cumuli resemble snow mountains." [28] They are naturally associated with more or less turbulent

[26] *Humphreys, William J.* Holes in the Air. Rept. Smithson. Instit. for 1912, pp. 257–268.

[A consideration of various types of air movements which the aviator is likely to meet. The classification is perhaps somewhat too detailed and the terms used, such as "aerial cataract," "breakers," "cascades," are likely to cause unnecessary alarm in a novice. The article is a suggestive one for the use of the teacher. The present writer has drawn on Prof. Humphreys' discussion in the paragraphs which immediately follow.]

[27] Pilot balloons are gas-filled spherical rubber or paper balloons of small diameter and without instrumental equipment. They are released for the purpose of determining direction and velocity of the upper currents, and have been followed to great distances and altitudes by means of special theodolites.—C. A. Jr.

[28] Lieut. Douglas Taylor, Royal Flying Corps.

("bumpy") conditions, of descending as well as of ascending currents. These conditions may extend to several thousand feet (10,000 feet more or less) above the surface. The base of cumulus clouds has a mean height above the surface of 4,600 feet (1,400 meters); while the tops average 5,900 feet (1,800 meters). Aviators report that "bumpy" conditions often occur on fine summer days even when there are no cumulus clouds. The explanation is that warm ascending currents are present, just as they are under cumulus clouds, but the rising air has not reached its dewpoint and hence remains clear. Probably, however, the most active ascending currents do not occur without cloud formation. It is easy to understand why fine, warm summer days, which would seem, at first thought, to give peculiarly steady flying conditions, are so "bumpy". Observations by means of kites and balloons have shown that the rate of ascent of the warm currents is often 10 to 12 feet per second. In thunderstorms this ascent is much more rapid.

All the air on a warm day can not be ascending. Descending currents are also inevitable. They may be met with in the clear space around the clouds; over the less easily warmed surfaces such as water, swamps, damp fields, and forests; and to some extent also intermingled with the rising movements. There is thus the difficulty of finding the machine tipping because it is partly in an ascending and partly in a descending current; or because it is between a rising or a descending current and the more or less quiescent air surrounding. Or, the aviator may run suddenly from an up current into a down current, and vice versa. Quick adjustments are often necessary. Under normal fine-weather conditions, however, such irregularities of air movements are not likely to be serious. It is well to remember that the turbulence of the lower air on a warm summer day is greatest during the warmer hours, and that the early morning and late afternoon hours are usually less cloudy and less "bumpy". During the warmer hours the surface wind also has a higher velocity, and is apt to be irregular and gusty, while the earlier and later hours are likely to be relatively calm. This is a practical point in connection with landing. The facts above noted about the surfaces over which there are apt to be the most active ascending, and those where there are likely to be descending movements, are also of practical value in flying. On clear, quiet nights, descending currents are likely down mountain slopes and in deep valleys, replacing the upslope currents of daytime.

Overcast days do not show the phenomena of local convectional air movements which have here been considered.

C. Effects of topography on air movements, combining both horizontal and vertical elements due to mechanical controls.

Wind near the ground is naturally variable and gusty. It is often forced to ascend or descend by the irregularities of the surface. Even where this surface is level, the lower air is retarded by friction and there is more or less descent of the faster-moving stratum just above. This results in a vertical interchange of air, of an irregular character. The extent to which such movements develop depends upon the amount of friction below and upon the relative velocity of the air currents. The surface wind is generally less gusty at night, hence this is as a rule the best time for flying. Sudden changes in the relation between the wind and the air currents just above the surface may be locally produced by alternating land and water surfaces, resulting in differing amounts of friction. Irregularities on the earth's surface cause many tangles, eddies, or waves in the moving air. Forests, buildings, all elevations or depressions, disturb the uniform flow of the lower air. In rising over an obstacle, such as a mountain range, or a hill, the air currents are likely to be congested, and their velocity increased. Winds are therefore usually stronger over mountain and hilltops, partly for this reason, and partly because of the faster movement of the upper currents. Again, when air rises over an obstruction such as an isolated hill, for example, it may be forced into a series of waves to leeward, and at the level of the hilltop. Such standing waves have been noted in the case of several mountains,[29] being sometimes visible because clouds form at the crests of the waves. There may be two or three successive waves, each one farther from the mountain top, and each one smaller than the last. These wavelike movements may cause temporary and local "bumps."

Prof. W. J. Humphreys, among others, has called attention most recently to the eddies which are likely to form on the leeward slopes of hills or mountains. The air comes down on the lee side in "cascadelike falls," which are more rapid the stronger the wind. Eddies are likely to develop close to the surface, the lower member of the eddy blowing up the slope, i. e., directly opposite to the general wind movement, which is downward. There are vertical down-currents on the down-slope, and vertical up-currents on the up-slope side of these eddies. The safe course is obviously to keep above the eddies and other irregularities of flow of the lower air. Eddies of this kind, combining both horizontal and vertical motions, are common close to the lee side of many obstructions; sometimes also, to a less degree, on the windward side. Aviators have many times reported active vertical currents in the lee of forests. In landing during strong winds, the close vicinity and especially the lee side of mountains, cliffs, hills, forests, in fact of obstructions of any kind, are likely to have disturbed wind movements. Decreased wind velocities will usually be found in sheltered localities, such as valleys transverse to the wind; as well as in forest clearings, where the wind is, however, likely to be very changeable, and to leeward of extended forests and of hills. In general, of course, by flying at greater heights, steadier winds will be found. The effect of surface irregularities upon the winds aloft is more marked, and extends farther, the greater the wind velocity.

CLOUDS.

Clouds are among the aviator's most serious meteorological handicaps, but they have two very practical uses: (1) They show the direction of the higher air currents, and (2) they are useful as weather prognostics. Accurate determination of cloud movements requires the use of a nephoscope and of a theodolite,[30] but somewhat rough but fairly satisfactory observations may be made noninstrumentally. A cloud patch, or some easily identifiable point in a cloud sheet, near the zenith, should be brought in line with the corner of the roof of a building, with the end of a branch of a tree, or with

[29] Green Mountain, on the island of Ascension, for example, as reported by the late Prof. Cleveland Abbe.

[30] *Abbe, Cleveland:* Treatise on Meteorological Apparatus and Methods. Ann. rept., Chief Signal Officer for 1887, Appendix 46. Washington, D. C., 1888.

Clayton, H. H., Discussion of the cloud observations made at Blue Hill Observatory, Mass., U. S. A. Ann., Astron. obsy. Harv. Coll., v. 30, pt. IV, 1896. Cambridge, Mass., 1896, 4°. pp. 273–278.

some other fixed object. As the cloud moves, the compass direction of its movement can roughly be determined. To have even such crude observations as these of value, some knowledge of cloud heights is necessary,[31] so that it may be clear at what altitudes the various wind directions, indicated by the observed cloud movements, will be encountered. Sometimes cloud directions for two or three different levels may be determined at the same time. The lower clouds, being nearer, seem to move faster, while the upper clouds, although actually traveling at greater velocities, apparently move much more slowly. It is impossible, therefore, without instrumental observation, to gain anything more than an indefinite, and sometimes indeed even a misleading, idea of the velocity of the upper currents. Cloud perspective also is a puzzling matter, but practice in watching cloud movements will soon enable anyone to make fairly accurate observations.[32]

A careful study of clouds as weather prognostics involves a long period of discriminating individual local observation and record. A few very general suggestions are here made. Further information may easily be secured by those who desire it.[33] Detached, scattered, isolated clouds are as a whole characteristic of fine weather. When, however, they become more numerous, spreading over the sky; when they arrange themselves in long parallel rows, giving the appearance of waves, and when they are followed by sheets of cloud, wet and perhaps stormy weather is indicated. Cloud sheets gradually spreading from the western horizon across the sky toward the east; becoming lower and darker; with rings (haloes, coronæ) around sun or moon; or with a "wet" moon and a "watery" sun, are storm prognostics.[34] *Wave* sheet clouds are still better rain prognostics. Even the general path of a storm with reference to the observer can often be foretold by cloud observation. For example, if thickening "mare's tail" cirri are seen diverging from the west or southwest they may serve as indications of a storm approaching from that quarter, which, as it moves eastward, is likely to affect the weather at the observer's station. On the other hand, when such clouds are seen diverging from the north, the storm is probably passing by to the eastward too far away to control the local weather.

Fog and low cloud sheets are very unfavorable for the aerial observer. They either make observation altogether impossible, as in the case of a fog, or they oblige him to fly so low, beneath the cloud, that he is within close range of the anti-aircraft guns; as in the case of stratus and nimbus clouds.[35] Isolated, detached clouds, on the other hand, may interfere with reconnaissance work, but do not stop it altogether. The clouds here selected for brief discussion from a practical point of view, are those which are most critical for the aviator. They are fog (not classed as a cloud by meteorologists), the lower sheet clouds, and the thunderstorm cloud.

Fog.—Typical land fog, which is the kind of fog that most frequently affects flying, occurs when there is little or no wind; under clear skies; chiefly on autumn and winter nights, although it is frequent throughout the year. In summer it usually "burns off" soon after sunrise; in the colder months it may last all day. This is a point worth remembering by aviators. The thickness of a fog sheet varies greatly according to conditions of weather and of topography. It may be only a few feet; it may be several hundred feet in a mountainous country. Typical land fogs form first and are thickest in the valleys and on lowlands. Hence they are often called valley and lowland fogs. When flying above a thick, widespread, dense fog sheet, it is impossible to see the surface. Hence it is essential that the distance above the ground should be known within very close limits. These fogs are favored by high pressures, because then the sky is apt to be clear and the wind light. Apart from the fog, the flying conditions are very favorable. The lower air is then very stable.[36] Fogs are formed in other ways, also, as in the case of damp winds blowing in from the sea (marine fog conditions), or when the mixture of different air currents leads to condensation. Such fogs may last for days. Coast fogs are generally more frequent in summer, while typical land fogs are more characteristic of fall and winter.

Lower sheet clouds.—At an altitude averaging less than 3,500 feet above the surface, but often reaching nearer, there is a high fog (*stratus*) whose relations to flying are much the same as those of ordinary fog. In fact stratus cloud is essentially, as its definitions puts it, "lifted fog in a horizontal stratum." It is, however, usually much thicker than an ordinary fog; does not rest on the ground, and lasts longer. It may be a typical fog which has been actually lifted from the ground, or it may have formed by mixture or by condensation between cool and warm air currents. There are, in fact, all gradations between fog and stratus cloud. It is common in winter, at night, and in higher latitudes. Although often mistaken for a rain cloud, stratus does not give precipitation, but it may precede rain or snow. Its vertical thickness varies greatly, and may reach a few hundreds of feet. It does not "burn off" as typical land fog usually does, and may persist for several days. Seen from above, stratus presents the appearance of a "sea of clouds." Its top may be very even, or may be in waves or billows. Reconnaissance work is practically impossible, but stratus is not a storm cloud and flying *above* it presents no special meteorological difficulties. Orientation is, of course, difficult or impossible. If the cloud sheet is not too thick, the upper surface of it, under certain favorable conditions, indicates the topography beneath, rivers and valleys appearing as depressions and mountains as elevations. This is a practical point worth remembering. Many aviators have been able to get their bearings in just this way. The temperature often increases for a time with ascent above the earth's surface when stratus clouds are present.

The ordinary rain cloud (*nimbus*) is another low sheet cloud which is likely to prevent aerial reconnaissance. This is the familiar low, dark blue, structureless cloud from which rain or snow usually falls, and below which broken irregular fragments of "scud" often drift. The base of the rain-cloud varies a good deal in height above the earth's surface. It averages under 6,500 feet (International Cloud Classification), and may be much lower. The Blue Hill results give its most frequent altitude as 2,000 feet. Of its vertical thickness little is definitely known. That it does not extend to great heights is clear from the fact that when openings occur in it, or when an

[31] *See* Atlas International des Nuages; *also* Illustrative Cloud Forms for the Guidance of Observers in the Classification of Clouds, by U. S. Hydrographic Office; *also* recent textbooks.

[32] A simple discussion will be found in *Ralph Abercromby:* Weather, 1887, pp. 87-92.

[33] See *H. H. Clayton*, loc. cit.; also *W. J. Humphreys*, Some weather proverbs and their justification, Pop. sci. mo., New York, May, 1911, pp. 428-444.

[34] At Blue Hill, Mass., cirro-stratus usually precedes rain by about 13 hours; alto-stratus, by about 6 hours.

[35] The complete classification of clouds, with illustrations and descriptive text, will be found in the "Atlas international des nuages" and in "Illustrative cloud forms for the guidance of observers in the classification of clouds," U. S. Hydrographic Office.

[36] See an important paper by Maj. *G. I. Taylor*, R. F. C.: The formation of fog and mist. Quart. journ., Roy met. soc., July 1917, 43: 241-268.

aeroplane flies up through it, higher clouds at elevations of 2 to 3 and up to 5 or 6 miles are often to be seen.[37] Aeronauts and aviators have frequently passed through and above the nimbus at an altitude between 6,000 and 7,000 feet. The duration of the rain cloud depends on the size, development, and rate of progression of the general storm (low pressure) conditions with which it is associated. It may last a few hours. It may, especially in winter, cover the sky for 2 or 3 days. A rising barometer and a change in wind are the usual indications of clearing, from the rain cloud to the broken clouds which follow a storm. Fog, elevated fog (*stratus*), and the ordinary rain cloud are thus all of them serious handicaps in aerial reconnaissance, because they are on or near the surface, and conceal that surface very effectively from above.

There is another sheet cloud, at a considerably greater height, which may be described. This is the more or less uniform sheet of bluish cloud, distinctly higher than the rain cloud [38] through which the sun or moon may be seen faintly, as through ground glass (*alto-stratus*).[39] This cloud usually precedes a general rain by a few hours.[40] It is not itself a rain cloud, but is associated with coming wet weather.

Thunderstorm cloud.—There are only two cloud types which ordinarily bring precipitation. These are the general rain cloud (*nimbus*) and the thunderstorm cloud (*cumulo-nimbus*). The former gives the persistent rains or snows of a general storm. The latter gives the shorter, usually heavier, and often squally rains (including hail) or snows. Of this type the summer thunderstorm is the obvious example.[41]

In view of its importance to the aviator, the thunderstorm cloud requires further mention. In a previous section (see p. 595) reference was made to the ordinary summer daytime cloud (*cumulus*) produced by local ascending warm currents. Aviators know well that under these conditions there is always more or less turbulence, which causes "bumps" in flying. These irregularities of ascending, descending and gently whirling air currents usually offer no serious difficulties. Often, however, the cumulus develops into a thunderstorm cloud (*cumulo-nimbus*), and then all these atmospheric movements are greatly accentuated. The cloud mass becomes extremely turbulent; the velocity of the ascending and descending currents increases; the heavy downpour of rain, perhaps mixed with hail, and the danger arising from the lightning, add to the difficulties. Vertical currents in thunderstorms may sometimes attain a velocity comparable with that of strong surface winds (Sir N. Shaw). In addition to receiving all possible assistance from the official weather forecast, the aviator should know how to predict the occurrence of local thunderstorms. He should, also, know enough about the characteristics of thunderstorms to be able to manage his machine to the best advantage in case he has to fly in one of them.

The typical thunderstorm cloud is an overgrown and greatly developed cumulus cloud. Its base is about three-fourths to 1 mile above the earth's surface, but is usually concealed by the falling rain. Its top varies from somewhat over a mile to 5 miles in extreme cases.[42] The thunderstorm type of cumulus has massive, hard rounded tops (thunderheads). The upper edges of these bulging tops very often, especially in the more severe thunderstorms, seem to become soft, and brushed out into a sheet or screen more or less fibrous and raveled (*false cirrus*), which gives the whole cloud, when seen from the side, the shape of an anvil. Or, the upper edges may remain hard and convex, like ordinary cumulus, while the delicate sheet of false cirrus floats around them. When, on a warm, muggy, summer day ordinary cumulus clouds are seen to be increasing in height, growing darker, joining, and especially when the screen or veil of false cirrus forms, local thunderstorms are likely to occur. Further, when a rising mass of cumulus is seen to develop a ring or "cellar" just below its top, caution is advisable. When, on the other hand, cumulus clouds break up, flatten and spread, and do not attain great height, the signs are favorable. The extraordinarily rapid upward growth of many cumulus and especially cumulo-nimbus clouds is due, at least partly, to the accumulation of the warm air below until it is able to break up through the overlying more stable strata. When once started, the warm air goes up with a rush, and the cloud may grow thousands of feet vertically in a very short time.

It is much the safer course for an aviator not to fly in a thunderstorm. But if he finds himself in the air when a thunderstorm is approaching, what shall he do? The meteorologist can give him a few suggestions. Thunderstorms in Europe, as well as in the United States, move in a generally easterly direction, at hourly velocities of 20 to 50 miles in the United States, and somewhat less in Europe. At any one time the storm itself has more or less of the shape of a convex lens, the convex side being on the front. The distance through the storm, from front to rear, is small, often less than 50 miles. Many of these storms are so small that it is perfectly easy to fly around them, on their northern or southern margins. On the other hand, the more extended ones, often called "line thunderstorms," may have a front extending roughly north and south for several hundred miles. An aviator can easily fly away from an advancing thunderstorm if such a course will not bring him into the enemy lines. He can also fly over the top of many of the smaller storms, and even over such of the larger ones as have not an excessive vertical development. If the top of the storm is so high that he can not fly over it, and no other course is open, the aviator should steer directly through the upper part of the cloud, facing the advancing storm. Usually a few minutes will bring the machine out into the rear of the storm. Thunderstorms are of many types and of many sizes and degrees of intensity. Hence it is quite impossible to frame rules which will meet every emergency. The possible damage to propellers or to wings resulting from large hailstones is considerably reduced by the fact that hail occurs over limited areas only and that many thunderstorms produce no hail.

It may be noted that airplanes can and do travel above the levels of many weather conditions (e. g., heavy rain or snow), which might be rather serious handicaps nearer the surface.

[37] E. g., alto-stratus, cirro-cumulus, cirro-stratus, alto-cumulus.

[38] The highest cloud sheet is the thin, delicate, milky, sometimes net-like *cirro-stratus;* formed of ice crystals; often producing haloes, and usually the first sheet cloud seen in front of an approaching storm. As the height of this cloud is between 5½ and 6 miles, it is beyond flying levels. At about 1 mile above the surface a grey cloud, of long rolls, usually covering the sky, often gives the appearance of a sheet but is, in reality, a broken cloud layer with lighter or open spaces between the separate rolls. This cloud (*strato-cumulus*) is common in quiet winter weather, and may persist for days. It makes the day dull and gloomy, and suggests snow or rain, but it is not a rain cloud. From above it has the appearance of "a gently undulating country".

[39] This belongs in the "intermediate" level, between 10,000 and 23,000 feet and averages about 3 miles above the surface.

[40] At Blue Hill Observatory rain follows *alto-stratus* in about 6 hours.

[41] Brief transient showers may, far less frequently, fall from two or three other cloud types, e. g., *strato-cumulus*.

[42] *Lieut. C. K. M. Douglas*, R. F. C., estimates that a height 6,000 feet from top to bottom is an absolute minimum at which cumulus clouds may develop into thunderstorms. On all occasions on which thunder occurred in France in 1916 the height of the cloud from top to bottom was not less than 19,000 feet. (*Journ., Scot. met. soc.* 3d ser., No. 33, 1916, 17: 65-73; *or* MONTHLY WEATHER REVIEW, Washington, March, 1917, 45: 93.)

WEATHER FORECASTING.

Surface conditions.

Whether in peace or in modern war the aviator usually has access to the official daily weather forecasts. He is not concerned with the collection of the meteorological data, with their charting, nor with the making of the forecasts. He should, however, understand, in a general way, the broad principles upon which modern weather forecasting depends. He should know how to interpret a weather map for himself. He should be able to make his own individual rough noninstrumental forecast, so that he may be able to fill in the gaps between the hours at which the official forecasts are made, and may not, if out of reach of an organized meteorological service, be perfectly helpless about probable coming weather conditions.

So far as the United States map is concerned, the information can easily be secured.[43] The British maps use millibars (see p. 593) and Absolute temperatures [32°F. = 0°C. = 273°A] instead of inches and hundredths and Fahrenheit degrees. The French maps use millimeters and centigrade degrees. Some idea of European weather types would be a most important and helpful addition to the meteorological knowledge of any aviator whose duty calls him to service in Europe. This subject has received a great deal of attention on the part of European meteorologists, and may be looked up without much difficulty.[44] The individual who makes his own noninstrumental local weather forecasts, without the help of a weather map, is in the primitive stage of forecasting. He must depend entirely upon weather signs or prognostics. The indications afforded by the systematic changes in direction and velocity of the wind [45] are usually the best guides. The aviator being especially concerned with the clouds and high winds which are commonly associated with cyclonic storms, will find it well to watch the wind carefully. "Backing winds," from easterly through north to westerly, indicate the approach and passage of a low pressure area on the south. "Veering winds," from easterly through south to westerly, indicate the approach and passage of an area of low pressure on the north. If a barometer is available, the barometric tendency, i. e., the rise or fall and the rate of rise or fall, should be constantly noted. In general, the approach and occurrence of foul weather are associated with a falling and a low barometer, and of fair weather with a rising and a high barometer.[46] Changes in wind direction mean changes in the distribution of pressure; i. e., in the location of the isobars and hence of the centers of high and low pressure. Changes in wind velocity alone, on the other hand, mean changes in the barometric pressure or pressure gradient, i. e., they mean that the distances between the isobars are increasing or decreasing. In addition to these indications, cloud prognostics, as above suggested, are very useful, and there are many good weather proverbs which, if rightly applied, are helpful.[47]

Forecasts of wind direction and velocity aloft.

The ordinary forecasts relate only to surface conditions. For the aviator, some idea of the probable wind aloft is obviously also important. Direct observation by means of small pilot balloons, whose course can be followed by means of theodolites, gives excellent indication of the direction and velocity of the upper currents up to ordinary flying heights. This method involves instruments and a certain amount of mathematical calculation, and must therefore be left to the trained meteorologists. Kites have also been used in this work. In the present war the Germans have evidently made extended use of pilot balloons electrically lighted at night. Direct observation of cloud movements also serves to give definite information of upper air currents. Here again, beyond the simple noninstrumental cloud observations above referred to, the trained meteorologist must be relied on to make use of his nephoscope and his theodolite, and to work out his results.

We come, then, to the already ascertained facts which may be of service in inferring the winds aloft. First, as to direction. For the first few thousand feet up (roughly, perhaps, 4,000–5,000 feet) the direction of the wind usually changes to the right, i. e., in a clockwise direction from that of the wind at the surface. Thus, if the wind at the surface is SW., the wind aloft may be expected to be more westerly; if the surface wind is N., the direction aloft is likely to be more from NE. With increasing distance from the surface, and decreasing frictional resistances, the winds tend more and more to follow the isobars.[48] This condition may be reached at about 1,500 feet, more or less, varying according to circumstances. In fact, different weather types and conditions exert so many varying controls that no hard and fast rule can be laid down. In general, however, it may be said that the shift in wind direction to the right is most marked near the beginning of an ascent, and up to 4,000–5,000 feet the winds may be expected to blow more or less along the isobar. At greater altitudes, above the influence of the surface gradients, the winds tend to come more and more from westerly directions, and easterly directions become less and less frequent.[49] The higher the flight, the greater will be the tendency of the air currents to blow from a westerly point. This is true in Europe as well as in the United States.

On fine, warm days, especially in summer, the lower air and the air somewhat above the surface tend to intermingle as the result of more or less vertical movement. The descending air currents bring down their own directions, and therefore there is a tendency for the surface wind directions to veer to the right during the day. At night, the tendency is to swing back again. This is known in meteorology as the *diurnal variation in wind direction*. In extremely favorable conditions, the shift may be as much as 90°. In the case of a prolonged flight, it must be remembered that the directions of both surface winds and upper currents are likely to be affected by the progression of the isobaric system as a whole.

Secondly, as to the velocity of the air currents aloft. On the average, this velocity increases with increasing altitude, up to the level of the highest clouds. Thus, from measurements of clouds, made at Blue Hill Observatory, Upsala (Sweden), and Potsdam (Germany), for example, the mean velocities of air movements at various levels are as follows:

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[43] *See* The Weather Map and its Explanation; and Wind-Barometer Indications, both published by the U. S. Weather Bureau, Washington, D. C.

[44] See, e. g., *W. J. van Bebber:* Lehrbuch der Meteorologie, 1890, pp. 317-343. Also: *J. G. Bartholomew*, Atlas of Meteorology, Edinburgh, [1899]. Plate 32, Text p. 35.

[45] Especially if supplemented by readings of a barometer.

[46] For the United States, the "Wind- arometer Table" (see footnote 43), gives the weather indications associated with various barometer readings and tendencies, combined with accompanying wind changes.

[47] *W. J. Humphreys:* "Some weather proverbs and their justification," Pop. sci. mo., May, 1911, pp. 428-444.

[48] This is known as the "gradient wind direction."

[49] In this connection the results regarding wind movements at all heights in cyclones and anticyclones obtained at Blue Hill Observatory are very important. See *H. H. Clayton.*—Discussion of the cloud observations made at the Blue Hill Observatory, Mass., U. S. A., *Annals Astron. Obsy. Harv. Col.*, Vol. XXX, Pt. IV, pp. 437-449.

See also chart 21 (Winds at Various Heights as Related to Barometric Pressure at the Ground) in *A. Lawrence Rotch & Andrew H. Palmer.*—Charts of the atmosphere for aeronauts and aviators.

For a summary of European results see *J. von Hann.*—Lehrbuch der Meteorologie, 3d ed., 1915, pp. 525-536, 541-545. In the United States, as shown by F. H. Bigelow and H. H. Clayton, and in central Europe, as shown by Akerblom, the low and high pressure areas of the earth's surface have comparatively little influence on the upper currents in the cirrus level.

Mean cloud velocities at different heights.

Levels.	1,600–6,500 feet.	6,500–13,000 feet.	13,000–20,000 feet.
	Mis./hr.	*Mis./hr.*	*Mis./hr.*
Upsala	20.4	19.5	35.8
Potsdam	20.8	23.0	37.8
Blue Hill	21.9	31.8	38.3

Two points may be noted in this connection. Cloud velocities can not be considered as giving accurate indications of air movement because (1) certain cloud types are commonly associated with certain special weather types, and because (2) the upper clouds can only be seen when not obscured by lower clouds. Further, for the aviator, mean velocities are much less critical than gustiness. The above table shows that there is an average increase in velocity from about 20 mis./hr. below a height of a little over 1 mile, to 35 to 40 mis./hr. at 13,000 to 20,000 feet. While the average velocity thus increases aloft, the gustiness usually decreases. Roughly, in the lower 1,000 to 2,000 feet the velocity may be expected to increase "as the height above sealevel." If, e. g., there is a wind of 15 mis./hr. at 500 feet above sealevel, a wind of 30 mis./hr. may be expected 1,000 feet above sealevel, and one of 45 mis./hr. at 1,500 feet. Finally, certain calculations which the aviator is not likely to have the time or opportunity to make for himself make it possible to predict, usually with reasonable accuracy, the wind velocities at about 1,500 feet, and up to, say, 3,000 to 4,000 or 5,000 feet.[50] At and near the earth's surface friction is a large and uncertain element in the problem. But at about 1,500 feet above the surface the effect of surface friction is slight. If the pressure gradient[51] be known, the "gradient-wind velocity" may be determined. This is the ideal wind, calculated from the gradient. It is the air movement needed to balance the pressure gradient. It also depends upon the density of the air, that is upon the temperature and pressure, and upon latitude. Tables have been prepared showing the gradient-wind velocities under varying conditions and at various latitudes.[52] The calculated results agree fairly closely with the results of observations made by means of kites and balloons. The complete formula is somewhat complicated, but a simple working basis is contained in the following table, adapted from one given by Prof. W. J. Humphreys.[53]

Table for calculating gradient-wind velocity.

Lat.	*Mis./hr.*
40°	$\frac{1900}{M} \times 2.24$,
50°	$\frac{1600}{M} \times 2.24$,
60°	$\frac{1400}{M} \times 2.24$.

M=number of miles between isobars.[54]

[50] It is perfectly feasible for the official forecasters to include the direction and velocity of the wind at 1,500 feet in their regular daily forecasts of surface conditions. They have been doing this abroad.

[51] The distance from one isobar to the next lower isobar, measured as nearly as possible at right angles to the two.

[52] *Great Britain. Advisory comm. aeronaut.* Report No. 9.
Great Britain. Meteorol. Office. Computer's Handbook, Sect. II. (M. O., No. 223).
Gold, Ernest. Barometric gradient and wind force. (Metl. O., No. 190.)

[53] In Prof. Humphreys' original paper (Jour. Franklin Instit., Phila., March, 1913, p. 234) the values are given for meters/second. The heading over his last column should read "Meters per second," not "Miles per hour."

[54] Formula as given by Dr. John Patterson, Meteorological Office, Toronto:

Lat.	*Mis./hr.*
40°	$\frac{3908}{M}$,
50°	$\frac{3279}{M}$,
60°	$\frac{2900}{M}$.

In the foregoing calculation it is assumed that the pressure gradient at 1,500 feet is the same as that at the earth's surface, as shown on the weather map. If we had isobaric maps for greater altitudes, the winds at those heights could be predicted. It is known that the arrangement of the isobars, and also the pressure gradients, change fairly rapidly with increasing elevation. For this reason, predictions of gradient-wind velocity (and direction) can not be absolutely relied on, and are limited to the lower few thousand (below 5,000) feet.[55] No definite rules can be laid down. Above the height at which the gradient velocity is reached, very diverse conditions are met. The velocity may increase. It may decrease. Indeed, the gradient velocity itself is not always reached. There is also a curious uncertainty about easterly winds. While westerly winds usually reach their gradient velocities at 1,500 feet or so, and then, as a whole, increase still further up to the maximum flying heights, easterly winds are very erratic both in changes of direction and of velocity. They do not show the same tendency to give gradient velocities. While westerly winds usually blow stronger at higher levels, easterly winds often decrease in velocity aloft, being then replaced by westerly winds. Easterly winds should therefore be carefully watched.[56]

On fine, warm summer days the surface wind very commonly blows strongest during the warmer hours, while the mornings, evenings, and nights are calm. This is known as the *diurnal variation in wind velocity*. It does not occur on cloudy or stormy days. Obviously, it is to be reckoned with in making a landing. Somewhat above the surface the variation in velocity is just the opposite. During the warmer hours, when the surface winds are blowing hardest, the air currents somewhat above the surface are slackened. At night, when the surface winds die down, the movement is more rapid aloft. The height to which this condition reaches depends on general weather conditions. When conditions are favorable, on hot summer days, it may reach nearly a mile. On such days, therefore, the aviator may find the wind velocity decreasing for a time as he ascends.

FAVORABLE AND UNFAVORABLE WEATHER FOR FLYING.

Summarizing briefly, high-pressure conditions are, on the whole, the most, and low-pressure conditions the least, favorable for flying.

High pressures as a rule have the advantage of lighter winds; of high and detached clouds; of fine weather. They have the disadvantage of being favorable to the formation of fog and of low stratus clouds, especially in winter, and during prolonged dry spells in summer a ground haze, which interferes with reconnaissance work, is common. High-pressure spells in summer are also apt to be times of active ascending diurnal currents, hence of "bumpy" conditions. The diurnal increase in wind velocity and the diurnal variation in wind direction are also best marked at such times.

Low pressures, on the other hand, are usually accompanied by general cloud sheets; by rain or snow; often by high winds, especially in winter. They thus bring conditions which may make flying difficult, ineffective, even impossible.

[55] Expected changes in surface pressure gradients are, to a considerable extent, predictable by the official forecasters.

[56] In England *Capt. C. J. P. Cave* has shown that different types of wind velocity distribution in the atmosphere prevail under different conditions. Thus, he has found cases when (1) the velocity remains steady even up to several thousand feet, (2) the velocity increases with height (usual condition), (3) the velocity decreases and then increases, (4) the velocity increases and then decreases.

WATERSPOUTS VISIT TATOOSH ISLAND, WASH.

By R. C. MIZE, Observer.

[Weather Bureau Office, Tatoosh Island, Wash., Jan. 10, 1918.]

Several small waterspouts were visible at sea, bearing south to northwest from Tatoosh Island, Wash., between 11:45 a. m. and 12:10 p. m. December 1, 1917. The greatest number observed at any one time was six.

A spout was first observed 2 miles southwest of the station at 11:56 a. m.; came within 200 yards of it six minutes later. During that time there was a gentle southerly breeze with a light flurry of moist snow. The sky was overcast with very dark nimbus clouds, all apparently moving from the southwest. The barometer rose from 29.63 to 29.67 inches in six minutes during the approach of this disturbance. There was no lightning. Some observers noted a slight roaring noise. The waterspout moved almost directly northeastward at the rate of 20 miles per hour until it reached the outer rocks, then swerved toward the north and headed directly for the Tatoosh Island lighthouse. Reaching the west side of this island, where the cliff is overhanging with a height of about 95 feet, the waterspout abruptly disappeared at 12:02 p. m. without any evidence of its presence upon the top of the island. It appeared to whirl counter-clockwise, as evidenced by the movement of the funnel cloud and spray. The diameter of the funnel cloud was apparently less than 20 feet, except near its upper extremity where it widened rapidly. The width of its path was about 50 feet and width of the core 5 feet. Heavy spray was thrown to a height of 20 feet, and lighter spray 80 feet or more.

METEOROLOGY OF GREENLAND'S INLAND ICE AND ITS FOEHN.[1]

By A. DE QUERVAIN.

(*Abstract of* paper presented to Swiss Society of Geophysics, etc., Zurich, Sept. 11, 1917.)

As the discussion of the observations by the Swiss expedition to Greenland is approaching completion, it has seemed proper to communicate these definite results which include the first observations made in summer and based on a complete traverse.

The communications have related chiefly to the thermal conditions (central region, daily amplitude, comparison with the fall observations by Nansen); to the régime of the winds with its pronounced diurnal variation; and finally to the annual growth of the inland ice and its probable evaporation during the summer.

The observations made while crossing Greenland, for the first time permit us to establish the fact that in some cases when a föhn is observed on the coast and on the inland ice it must be a wind descending from somewhat in the interior if not indeed quite from the summit line itself of the inland ice.

More ample details will be found in the full report to be published at an early date in the Mémoires de la Société helvétique des Sciences naturelles, volume 53.

VARIATIONS OF ALPINE GLACIERS.

[*Reprinted from* Nature, London, Jan. 3, 1918, **100**: 350.]

Prof. P. L. Mercanton, in "Revue générale des Sciences" for November 30, 1917, discusses the results of the more recent observations on the advance and retreat of glaciers, particularly Alpine. Systematic work was begun by Prof. Forel 37 years ago in the Swiss Alps, and for at least 30 of them the movements of the Rhone Glacier and the two at Grindelwald, have been carefully noted. Those on the northern side of Mont Blanc have also been studied, and similar work is now being carried on in other ice fields. But the main advances and retreats of those glaciers and a few others in the Alps, are known for fully three centuries and estimates of their periods have been attempted. These do not correspond with Wolf's 11-year period, or with the 35-year one of Brückner. Some causes affect their movements, other than the snowfall in the upper region or névé and the ablation due to temperature changes in the lower; for of two adjacent glaciers, one may be advancing while another is retreating. Recent observations, as Prof. Mercanton points out, indicate that the volume and the length of a glacier can to some extent vary independently, or, in other words, that the ice moves down a valley from the more expanded névé basin at its head, not with perfect uniformity, but with local intermittance, so that a belt near the end may be swelling up in a wide mound and thus the actual volume of ice be increasing, while the end itself is in retreat. Prof. Mercanton observes that the subject of glaciers and their history is not yet exhausted.

AQUEOUS EXCHANGE BETWEEN THE NÉVÉ AND THE ATMOSPHERE.[2]

By R. BILLWILLER.

(*Abstract of* paper presented to Swiss Society of Geophysics, etc., Zurich, Sept. 11, 1917.)

Many glaciologists have in the past occupied themselves with the question whether the Alpine glaciers and névés condense some of the water vapor in the atmosphere or, on the contrary, contribute water to the atmosphere by evaporation. The admirable study by Charles Dufour and F.-A. Forel[3] has not settled the question, nor rendered useless new and precise measurements. On the contrary it is important to resume the problem in the light of more extended and more conclusive experiments than theirs. It seems that Dufour and Forel overestimated the frequency and quantitative importance of condensation, basing their conclusions on the results of 15 days of observations made at the height of summer and at the front of the Rhone Glacier, i. e., under conditions of place and time most favorable to an energetic condensation.

The frequency of condensation or evaporation at a given location is best determined from regular observations on the temperature and the humidity of the air and of the temperature of the snow surface. I hope to be able to study the conditions of the Säntis from this standpoint.

The quantity of water condensed or evaporated is determined by weighing. For this purpose I have at present a special balance built after specifications of Prof. Dr. A. Picard, and conveniently carried in the satchel. It has functioned very nicely and so far has furnished the following determinations:

October 14 and 15, 1916, there was uninterrupted evaporation during 24 hours on the Säntis; the maximum was 0.071 mm. per hour, between 7^h and 8^h.

[1] *A. de Quervain* (Zurich). Sur la météorolocie de l'inlandsis du Grönland et en particulier sur le föhn de l'inlandsis. Arch. des sci. phys. et nat., Genève, 15. Nov. 1917, 44.

[2] *R. Billwiller* (Zurich). L'échange aqueux entre l'air et le névé. Arch. des sci. phys. et nat., Genève, 15. Nov. 1917, **44**: 358-359.

[3] *Dufour & Forel*. Recherches sur la condensation de la vapeur aqueuse de l'air au contact de la glace et sur l'évaporation. Bull., Soc. vaudoise des sci. nat., Lausanne, 1871, **10**: 621-684.

January, 1917, a very interesting series of 8 days toward the close of the month, on the Schatzalp (above Davos) gave the type of aqueous exchange under the régime of a calm winter anticyclone. During the night, by reason of the considerable fall in temperature of the snowy surface, a slight condensation intervened (e. g., night of Jan. 22–23, a mean of 0.007 mm. per hour); but from sunrise to sunset a many times larger amount evaporated (e. g., on Jan. 23 = 0.036 mm. per hour).

On the other hand I have determined persistent condensation on the Saint-Gothard during the summer weather of May, 1917, a period when—during the warmest hours—there was equilibrium between the vapor pressure of the air and of the snow bed, but where condensation always prevailed when this did not obtain; the maximum was 0.110 mm. per hour in the night of May 25–26 and during a strong north wind. Of course, the special conditions in the col (high wind with accentuated vertical component) increased the condensation as compared with other stations.

The complete observations will be published and discussed elsewhere.

USE OF MONTHLY MEAN VALUES IN CLIMATOLOGICAL ANALYSIS.

By E. G. BILHAM.

(*Abstract of* paper presented before the Royal Meteorological Society, London, Dec. 19, 1917.)

[*Reprinted from* Nature, London, Dec. 27, 1917, 100: 340.]

The objects of the paper are (1) to determine to what extent computations based on calendar monthly mean values are vitiated by the fact that the latter are of unequal length; and (2) to provide means of applying numerical corrections on account of errors arising from this cause.

The mean month is defined as an exact one-twelfth division of the year, or 30.437 days, and that period is used as the standard to which the results derived from the actual months are reduced. The matter is of special interest in connection with the computation of Fourier coefficients to represent the seasonal variations of a meteorological element such as temperature. Regarding the year as a cycle of 360°, errors arise from the fact that the monthly mean values will in general differ by small amounts from the ordinates of the curve corresponding with 15°, 45°, etc. The corrections to be applied to the original monthly means and to the Fourier amplitudes have been determined. The use of these corrections is suggested as an alternative to the employment of 5-day means in cases where special accuracy is required.

BATHYRHEOMETER AS ANEMOMETER.

Y. Delage describes in the Comptes Rendus of the French Academy of Sciences,[1] experiments looking toward the adaptation of his bathy-rheometer to the purposes of the anemometer. The bathy-rheometer consists essentially of a staff about a meter in length carrying at its upper free end two metal plates mutually perpendicular and of areas sufficient to perform the work expected of them; while the lower end of the staff is attached to a gimbal support, is heavily counterweighted, and probably will be provided with a damping device to counteract the tendency of the staff to vibrate in the rare atmosphere under the influence of wind puffs. One of the two metal plates or fins acts as the tail of a windvane, being attached by one edge longitudinally to the top of the staff. The fin perpendicular to the vane-fin is set at an angle of 45° with the axis of and sloping upward away from the staff. Its reaction against the horizontal or inclined air currents tends to depress the staff to a definite amount depending on the velocity of the wind. The orientation and the amount of depression of the staff are recorded by suitable mechanisms linked to the counterweight.

M. Delage designed this instrument to measure and record aqueous motions associated with wave phenomena, and was led to apply it to anemometry by the suggestion of Bayeux who thinks that the device is better adapted to anemometric work in high localities than the usual windmill type of instrument, which frequently loads up with rime and glaze until it can not function. It would seem, however, that the adapted bathy-rheometer is equally liable to give false indications, though some kind of a record will undoubtedly be secured. It is the experience of the Weather Bureau that the tails of the standard windvane, equally with the cup arms of the Robinson anemometer, are subject to loading up heavily with rime and glaze under certain American weather conditions. This would certainly happen to the fins of the bathy-rheometer also, under such weather conditions, thereby giving a temporary "set" to the staff with its overhanging fins, and certainly modifying temporarily the fundamental angle of inclination of the inclined fin.

Furthermore, Delage himself has recently found and, to a certain extent, discussed[2] another source of error inherent to the instrument whether immersed in water or air, viz, vortex movements which are intensified in the stronger currents and cause an erratic registration. On the records by the instrument "these abnormalities appear as parasitic curves which are hard to distinguish" and a mechanism for reducing the disturbing vortex movements has not yet been perfected.

In the first of the two papers cited the author describes and illustrates the meteorological application of his device and works out some formulæ for interpreting its records.—C. A., jr.

NITRITES FROM NITRATES BY SUNLIGHT.[3]

By Prof. B. MOORE.

(*Abstract of* paper presented before the Royal Society, London, Dec. 13, 1917.)

[*Reprinted from* Nature, London, Dec. 27, 1917, 100: 338.]

Dilute solutions of nitrates exposed either to sunlight or to a source of light rich in light-energy of short wavelength (such as light from a mercury vapor arc inclosed in silica) undergo conversion of nitrate into nitrite. There is an uptake of chemical energy in this reaction transformed from light energy, as in the formation of organic carbon compounds in foliage leaves; it is to be added to the relatively small number of endothermic reactions induced by light. When green leaves are immersed in nitrate solution comparatively little nitrite accumulates, indicating that nitrites are rapidly absorbed by the green leaf. Nitrates taken up by plants from soil would, in presence of sunlight, be changed to nitrites, which are much more reactive than nitrates. This indicates that the early stages of synthesis of nitro-

[1] *Delage, Yves.* Utilisation du bathyrhéomètre pour l'anemométrie dans les régions froids. Comptes Rendus, Paris, 12. nov. 1917, 165, 659-666.

[2] Delage, Y., *in* Comptes rendus, Paris, Aug. 27, 1917, 165: 277-283.

[3] *Moore, B.* The formation of nitrites from nitrates in aqueous solution, by the action of sunlight and the assimilation of the nitrites by green leaves in sunlight.

genous compounds are carried out in the green leaf and aided by sunlight. Rain-water collected for a considerable time contains no nitrites, all having been oxidized to nitrates; but if exposed to bright sunlight or ultra-violet light for a few hours a strong reaction for nitrites is always obtained.

There is no hydrogen peroxide or ozone in air at surface level. The fresh odor in open air, commonly referred to as "ozone," is probably nitrogen trioxide, which at high dilutions has the odor of ozone. The oxides of nitrogen are probably formed by the action of sunlight, rich in ultra-violet rays, in upper regions of the atmosphere upon air and aqueous vapor.

CENTENNIAL OF METEOROLOGICAL STATION AT THE GRAND SAINT-BERNARD.[1]

By R. GAUTIER.

[*Abstract of* paper presented to Swiss Society of Geophysics, etc., Zurich, Sept. 11, 1917.]

On the occasion of the centennial of the installation of a meteorological station at the Hospice of the Grand Saint-Bernard by Marc-Auguste Pictet, September 15, 1817, the director of the Observatory of Geneva, Mons. R. Gautier, proposed to the general assembly of the Société Helvétique des Sciences Naturelles that there be transmitted to the canons of the Grand Saint-Bernard, a memorial bearing a large number of signatures of members of the society.

In this connection Mons. Gautier made some remarks concerning the installation, and the gradual improvement of the station in 1829 by Auguste de la Rive, afterward several renewals by Émile Plantamour in 1883, by Émile Gautier, and finally in 1900, 1903, 1916, and 1917, by himself.

In 1900 the station was transferred from the old building to the new one, and since that time the observing hours—which had been following the changes in effect at the Geneva Observatory—have been fixed at the three official terms for all the Swiss meteorological réseau.

Interesting climatological results are given in Ch. Bührer's note "Le Climat du Grand St.-Bernard" (Lausanne, 1911), and in the splendid monograph "Das Klima der Schweiz" by Maurer & Bilwiller. There is in preparation at the Geneva Observatory, a work on the whole 100 years of observations.

TIME-ZONES AT SEA.

[From the report of the Council of the Royal Society of Great Britain, as *abstracted in* Nature, London, Dec. 6, 1917, p. 275.]

The possibility of introducing a more convenient system of timekeeping at sea has lately been under consideration, both in Great Britain and in France. The conclusions reached at a conference under the chairmanship of the Hydrographer to the Admiralty, in which representatives of scientific societies took part, are included in the report of the council. The most practical method of obtaining uniformity is considered to be the establishment, outside territorial waters, of zones corresponding with the hourly zones on land. It is proposed that the zone extending from 7½° east to 7½° west of Greenwich should be the zero zone, and that the other zones west and east should be respectively described as *plus* or *minus*, with an indication of the actual correction required for reduction to Greenwich time and date. On this system "+12" would be the half-zone east of the "date line" and "−12" the half-zone west. Any alteration of the time of clocks in ships should always be one hour, but the instant of making the change need not necessarily be that of passing to a new zone. In the case of self-recording meteorological instruments, which it would be difficult to adjust for changing zone time, Greenwich time is considered most convenient, but ship's time should be used for the regular observations. If the proposed zone times be generally adopted, it is recommended that the receipt and dispatch of telegraphic and other messages should for the immediate future be recorded in zone time; but, eventually, it would be most convenient for such purposes to adopt Greenwich time throughout the world

[1] *R. Gautier* (Genève). Le Centenaire du Grand St-Bernard. Arch. des sci. phys. et nat., Genève, 15. Nov. 1917, 44: 351.

Baron Dairoku Kikuchi, 1855–1917.

By Dr. T. C. MENDENHALL.

[*Dated:* Ravenna, Ohio, Jan. 14, 1918.]

Baron Dairoku Kikuchi, one of Japan's most distinguished educators and men of science, whose death occurred in August last, was so well known in America, not only through his published works but also personally, that something more than a formal obituary note will doubtless be welcomed by readers of the MONTHLY WEATHER REVIEW.

Dr. Baron Dairoku Kikuchi, privy councilor, president of the Imperial Academy, honorary professor of the Imperial University at Tokyo and also of the Imperial University at Kyoto, was born on March 17, 1855, in the city of Yedo, now Tokyo. Both his father and grandfather were noted scholars in their day, especially in the, to them, greatly restricted area of human knowledge known to the Japanese as "Western learning."

The system of heirship by adoption and change of name, so long in use in Japan, gives rise to much confusion among foreigners regarding relationship and many men of science in Europe and America who have known and admired both Kikuchi, minister of education, mathematician and author of many works, and Mitsukuri, eminent zoologist and writer of international reputation, have not known or suspected that they were brothers. Kikuchi's father was Shuhei Mitsukuri, who had been adopted by Gempo Mitsukuri as his heir. He had belonged to the house of Kikuchi, and to this name his son Dairoku succeeded when it was vacated by his father. Dr. Kakichi Mitsukuri, the distinguished naturalist, was a younger brother and bore the name of the father.

In his early boyhood Kikuchi was famed for his precocity, and it is said that at the age of 9 years he was "a teacher of others." In 1866 the old Shogunate Government sent to England a number of promising young men, who were to absorb the best, if possible, of that Western learning and culture which was already pounding heavily at the closed portals of Japan. Many of these afterward rose to distinction and the youngest of them all was Dairoku Kikuchi, 11 years of age. In two years he returned to his native land, when again, at the mature (?) age of 13 years, he engaged in teaching. At the same time he was a most industrious student, and two years later he was ordered back to Europe to complete his studies. In the University of London, and afterward at Cambridge, he distinguished himself. He was one of the "wranglers" of the latter, of the year 1877, a group of

men several of whom afterward achieved fame, including Sir Charles Parsons, inventor of the steam turbine which has well-nigh revolutionized both the theory and practice of prime motors. In the same year he returned home to receive the appointment of professor of mathematics in the institution in which he had as a boy studied and taught, and which was rapidly developing into the Imperial University of Japan. His success in this important position was assured from the start. To do special work in his department he attracted some of the most brilliant of his young fellow-countrymen, who afterward shared with him in the labors and rewards incident to the phenomenally rapid evolution of public education in Japan. In addition to his accomplishments as a mathematician Kikuchi soon gave evidence of a rare fitness for "affairs" of an administrative and directive nature, which greatly enlarged his sphere of usefulness, as is shown in the following list of some of the more important posts to which he was called, the duties of which he discharged with great credit to himself and lasting profit to his country.

Professor of mathematics at the Imperial University, 1877–1898; Dean of Science College of the same, 1881–1893; president of the same, 1898–1901; president of the Imperial University at Kyoto, 1908–1912; Director of the Bureau of Special Education in the Department of Education (Imperial Government), 1897; Vice minister of Education, 1897–1898; Minister of Education, 1901–1903; in the Imperial Diet as Crown member of the House of Peers, 1890–1912, resigning when he was a made a Privy Councillor which he continued to be up to his death; member of the Imperial Academy since 1889, and president from 1909 until his death, having been elected three times in succession. Only a few months before the end came he had been appointed the first director of the newly created National Physico-Chemical Institute.

During his long career—which in spite of his premature death covered a period of 40 years—he was frequently called upon to serve his country abroad as its representative on scientific commissions and among learned bodies. In 1884 he came to the United States as delegate to the International Prime Meridian and Universal Time Congress held at Washington, and on his way home through Europe he remained some time in Germany, making a thorough study of the educational institutions and systems of that country. In 1907 he represented the Japanese Imperial Academy at the General Meeting of the International Association of Academies at Vienna; but his most important work during that year was the delivery, in English, of a course of lectures on Japanese education at the University of London. These lectures, somewhat revised, were afterward published in a single large volume by John Murray, London. In his boyhood Kikuchi had acquired a rare mastery of the English tongue and this, with a critical knowledge of his own language, enabled him to produce in this volume a storehouse of information regarding the history, development, and scheme of education in Japan, in which the most exacting student of that subject is not likely to find anything lacking. In its pages much light is thrown on many principles and practices of the Japanese which have hitherto been obscure to people of other nations; and perhaps in no other volume can one get so good an understanding of that marvelous "naissance" of a great nation during the life of a single generation, that continues to be a mystery to many thoughtful people. The universal interest in the subject is evidenced by the fact that on the occasion of a second visit to this country, in 1909, he found audiences in many of our principal cities eager to hear him on one phase or another of the same topic.

At home, in addition to the work incident to the more formal appointments enumerated above, Kikuchi's services were always in demand as a member of numerous committees for the study of scientific or educational problems, and his opinion always carried great weight.

The establishment of the very important Earthquake Investigation Committee was secured by him while a member of the House of Peers. He was one of the originators of the Tokyo Mathematical Society, which was founded in 1877, shortly after his return from Cambridge. It was the pioneer of the many learned societies that have since been created in Japan and at his suggestion it became, in 1884, The Tokyo Mathematico-physical Society. At an early period he became interested in the mathematics of the old Japanese school and his original investigations were practically confined to a critical examination of their methods and results. His numerous activities in other directions left him little leisure for this work, but in his spare hours he accumulated a mass of information of which, unfortunately, only a part reached publication before his death. But it was a labor of love, and in choosing this as the material upon which to exercise his powers of mathematical research he exhibited a fine patriotism, preferring to demonstrate that his intellectual ancestors were not lacking in the "divine afflatus" of mathematics (which had been denied them by many foreigners) rather than to seek fame and reputation for himself.

In the same unselfish way he devoted much time, at the request of the Imperial Department of Education, to the preparation of a textbook on elementary geometry for use in the secondary schools of Japan. This work involved technical difficulties quite unknown to the western author, many of which, indeed, can not be easily explained. Some of them grew out of the ordinary practice in Japan of writing in vertical lines from top to bottom, the lines succeeding each other from right to left. Kikuchi had the courage to cut this Gordian knot by substituting the European fashion of writing in horizontal lines from left to right, a practice which has since been universally followed in mathematical publications.

Loaded with honors and charged with duties of the greatest importance and responsibility, he died suddenly, from a stroke of apoplexy, at his seaside villa at Chigasaki on the morning of August 19, 1917. His funeral took place in accordance with Shinto rites on August 23, and his remains, after being cremated, were interred in the Yanaka Cemetery.

He was created a baron in 1902 in recognition of his invaluable services in the cause of education in Japan and for his share in the Anglo-Japanese alliance which was brought about while he was in the cabinet.

My own acquaintance and intimate relations with Baron Kikuchi began 40 years ago, soon after his return from England, with his mathematical honors, to become a professor in the University at Tokyo.

He had ardently identified himself with his associate and close friend, Prof. Toyama, and others of a small group of "the youngest and best" of Japanese scholars and publicists, in the establishment of a sort of "lyceum" or lecture platform, principally for the benefit of civil and military officers whose occupations and years prevented their becoming students in the university and whose ignorance of European languages stood in the way of their making use of libraries and collections of books in which "western learning" was stored. The scheme was not looked on favorably at first by the Government, the

fear being that doctrines too radical for the time might be preached from this forum, but when the real object of the young men interested was fully understood restrictions were removed. It was the first enterprise of its kind in the history of Japan and was so successful that after a few years it was able to acquire a building or hall of its own, constituting an event of real importance in the evolution of this rapidly changing nation. The audiences were large and enthusiastic from the start and specially eager to learn of the discoveries in science and their practical applications in Europe and America. It was my good fortune to be invited to give several courses of lectures to these men, sometimes in a large theater and sometimes in a large Buddhist temple from which the "gods" and other insignia of worship had been temporarily removed.

Those using other than the Japanese language must necessarily have an interpreter, and when I stood before one of these audiences for the purpose of explaining some of the more recent advances in physical science and their applications, it was the boyish-looking professor of mathematics who stood at my side to render my words intelligible to them. The difficulty of this task will be recognized when it is remembered that at that time the Japanese vocabulary included practically no equivalents for the numerous technical and scientific terms necessarily made use of in such discourses.

Since then, by the indefatigable and wisely directed labors of native scholars, the language has been so enriched that this difficulty no longer exists. Then, however, the task of explaining the meaning of these terms fell upon the interpreter, and because of his training in the exact sciences at Cambridge and his excellent and ready knowledge of both tongues, it is doubtless true that no other person in the world could have done it so well.

The acquaintance thus begun quickly ripened into a close friendship, which stood the test of years and distance and ended only with his death.

Kikuchi made a somewhat prolonged visit in the United States in 1884 as delegate to the International Time Congress, making friends of all whom he met; another in 1909, already referred to; and a third, planned for the winter of 1917–18, was prevented by his death.

Due perhaps to his having mingled with them at an early age and during his most receptive years, his association with foreigners always seemed somewhat easier and less formal than is the case with many of his countrymen, among whom one may often note a sort of unconscious aloofness or reticence in their relations with other races. He possessed a keen sense of humor, which, however, is by no means uncommon among the "intellectuals" of the Land of the Rising Sun. There was about him a charm of manner and refinement of conduct that endeared him to all who had the good fortune to know him intimately. Whatever trace of race prejudice one might have retained through inheritance or otherwise, it was never called up by Kikuchi's presence. Indeed, he was a type of "scholar and gentleman worthy of any race or time."

To show the esteem in which he was held among his own people I can do no better than to quote from a tribute, published soon after his death, by one of his favorite pupils in the early years of his teaching (and one of mine during the same period), Dr. R. Fujisawa, later his successor as professor of mathematics in the Imperial University, to whom I am greatly indebted for information relating to Baron Kikuchi's earlier life. He says:

> It has fallen to the lot of very few men of learning to preside over the progress of education and the advancement of knowledge for over 40 years with unfailing sagacity and unbroken success. If "luck" can be said to have aided him at all, it was to be found in the happy coincidence that his talent and disposition so well harmonized with the time and surroundings in which he lived. Kikuchi's name will go down in Japanese history, and it will be remembered of him that although he attained the highest honors his country could bestow on one who emerged from the often-neglected circle of scientific men, he remained from first to last the same genial, modest, courteous man, the same warm-hearted and unchanging friend, the same loyal and devoted servant of his sovereign and his country.

The late Prof. Abbe was among the warm friends and admirers of Baron Kikuchi and maintained a correspondence with him up to about 1911. The acquaintance probably began in 1875, when Prof. Abbe was in active correspondence with a number of leading Japanese and urging the establishment of a national centralized weather service which should coordinate and centralize the sporadic and independently managed Japanese observatories of that day. When Baron Kikuchi visited the United States and Washington in 1884, he was naturally among the guests at the home in I Street where Prof. Abbe was entertaining other delegates to the International Prime Meridian Congress, in whose activities he was taking a leading part. This opportunity for personal acquaintance was always one of the happiest memories of those days, and the mutual esteem then developed steadily increased. It seems altogether appropriate that the above memorial by Dr. Mendenhall should appear on the pages of the REVIEW instituted by Prof. Abbe.—C. A., jr.

Rollin Arthur Harris, Ph. D., 1863-1918.

Dr. R. A. Harris, who died suddenly on the streets of Washington, D. C., January 20, 1918, was one of the world's authorities on the laws and motions of terrestrial oceanic tides and had been a mathematician in the Tidal Section of the United States Coast and Geodetic Survey since 1890. He had also contributed to the perfecting of the Coast Survey's tide-predicting machine.

Harris was born in Randolph, N. Y., April 18, 1863. took his undergraduate degree from Cornell University in 1885 and his Ph. D. in 1888, afterwards spending a year at Clark University, Worcester, Mass. The obvious relationship between tides oceanic and tides atmospheric, as well as Harris's powers of mathematical analysis, secured and kept for him the liveliest interest and appreciation on the part of Prof. Cleveland Abbe. Harris was persuaded to contribute several papers to the pages of the MONTHLY WEATHER REVIEW, and they are listed below.

A partial explanation of some of the principal ocean tides. (Read before the National Academy of Sciences, Apr. 19, 1900.) MONTHLY WEATHER REVIEW, March, 1900, **28**: 103–108 and map.

Note on the oscillation period of Lake Erie. MONTHLY WEATHER REVIEW, June, 1902, **30**: 312 and fig.

The semidiurnal tides in the northern part of the Indian Ocean. MONTHLY WEATHER REVIEW, March, 1903, **31**: 127–133 and 5 figs.

Early knowledge of the tides at Panama. MONTHLY WEATHER REVIEW, February, 1906, **34**: 80–81.

Deflecting force due to the earth's rotation. MONTHLY WEATHER REVIEW, October, 1908, **36**: 327–328.

Dr. Harris also prepared an extended critical review of the last edition of Krümmel-Boguslawski: Handbuch der Ozeanographie, which the REVIEW was unable to publish. The critique eventually appeared elsewhere.

Joining the Coast and Geodetic Survey in mourning the loss of an extremely modest but able and illustrious colleague, the Weather Bureau particularly regrets this loss of a helpful and sympathetic friend to the advancement of the higher meteorology.—C. A., jr.

RECENT DISTINCTIONS IN METEOROLOGY.

ROYAL MEDAL OF THE ROYAL SOCIETY (LONDON).[1]

One of the Royal Medals was conferred, November 30, 1917, on Dr. J. Aitken, who is distinguished for his life-long researches on the nuclei of cloudy condensation, embodied in a series of memoirs communicated to the Royal Society of Edinburgh. The latest of these appeared in the present year. Dr. Aitken's discoveries opened up a new field of investigation in physics and constitute a chapter of knowledge of great importance intrinsically and in their relation to the physics of meteorology. Dr. Aitken, who has pursued his work as an amateur, has displayed great experimental ingenuity, and his remarkable construction of the "dust counter" has provided a permanent scientific appurtenance of precision to the physicist and climatologist. Among other contributions to science Dr. Aitken has made important advances in our knowledge of the formation of dew.

SYMONS MEMORIAL MEDAL, 1914.

The Symons Memorial Gold Medal of the Royal Meteorological Society, London, was awarded in 1914 to Mr. William Henry Dines, F. R. S., in recognition of his distinguished work in connection with meteorological science. In recent years Mr. Dines has been best known to American students through his observations and researches on upper-air conditions in England. He also devised two meteorographs for this work.

SYMONS MEMORIAL MEDAL, 1916.

The presentation of the Symons Memorial Gold Medal for 1916 was made on January 19, 1916, to Prof. Alfred Angot, of the Bureau Central Météorologique de France, having been awarded to him at the meeting of November 17, 1915. The following statement is from the minutes of that meeting:[2]

Prof. Charles Alfred Angot was born in Paris in 1848. He has held the position of professor of physics and meteorology in the Institut National Agronomique of Paris, and has been on the staff of the Bureau Central Météorologique since 1879. In 1907 he succeeded to the directorship of the latter on the retirement of M. Mascart. In the same year he became a member of the International Meteorological Committee.

His contributions to meteorological science have been many and varied. His earlier researches were devoted to actinometry and solar radiation. He is also the author of important papers on the wind records of the Eiffel Tower, on the diurnal variation of the barometer considered as a world phenomenon, and on the rainfall of western Europe and of the Mediterranean basin. His most recent publications, entitled "Études sur le climat de la France," form a comprehensive study of the climatological data collected by the French Bureau. Up to the present only the elements, pressure, temperature, and wind have been dealt with.[3]

M. Angot is also the author of a well-known textbook of meteorology (3d ed., 1916), of the official instructions to observers of the French meteorological service, and of tables for the reduction to mean sealevel of barometer readings.

SYMONS MEMORIAL MEDAL, 1918.

The Royal Meteorological Society has awarded the Symons Memorial Gold Medal for 1918 to Dr. Hugh Robert Mill, D. Sc., LL.D., a former president of that society, in recognition of his services to meteorological science. Dr. Mill is widely known as the present Director of the British Rainfall Organization (founded by G. J. Symons), as the editor of its annual volume "British Rainfall", and as the editor of Symons's Meteorological Magazine. The latter was started by G. J. Symons as a monthly publication of the observations of the Rainfall Organization when he established the latter, but has grown to be a useful popular meteorological magazine of wider scope.

Besides many papers on the rainfall and the meteorology of the British Isles Dr. Mill has written our well-known text, The Realm of Nature, and is the editor in chief of that compendious international geographical text The International Geography. Dr. Mill was born in Thurso, Scotland, in 1861, so we are justified in hoping that he has yet many years of usefulness before him.—C. A., jr.

FOUNDATION MEDAL OF ROYAL GEOGRAPHICAL SOCIETY, QUEENSLAND.

The Editor is informed that Dr. Griffith Taylor, Physiographer to the Commonwealth Bureau of Meteorology, Melbourne, has recently been awarded the Foundation Gold Medal of the Royal Geographical Society of Queensland, in recognition of a lengthy thesis, illustrated by 36 maps, on the "Tropical Settlement of Australia." One aspect of the problem there treated is summarized in the quotation on page 589 above. A previous carefully worked-out report on elements entering into the problem is mentioned in the footnote on page 590. Other papers by Dr. Taylor have been noticed in the MONTHLY WEATHER REVIEW for July and October, 1916. His studies in Australian climate and geography are already well known to students of that continent.

[1] Nature, London, Dec. 6, 1917, **100**: 276–7.
[2] Quarterly journal, Royal meteorological society, London, April, 1916, **42**: 124, with portrait.
[3] Recently he has made the following contribution: Régime pluviométrique de la France, par *A. Angot*. Ann. de géographie, Paris, 15 juillet 1917, **26**: 255–272.—C. A. jr.

SECTION III.—FORECASTS AND WARNINGS.

FORECASTS AND WARNINGS, DECEMBER, 1917.

By ALFRED J. HENRY, Supervising Forecaster.

[Dated: Weather Bureau, Washington, Jan. 22, 1918.]

The exceptional features of the weather in December, 1917 was the pronounced and enduring cold that prevailed east of the Rocky Mountains and the abnormal warmth on the Pacific Coast. The statistical details of the cold weather will appear in Section VII of this REVIEW. The aspect of the weather that most impressed the forecaster was the southward and the eastward sweep of anticyclones from the Canadian Northwest; the large number of partly developed cyclones that drifted southeastward from the northern Plateau Region and the small number that eventually reached the Atlantic coast. Twelve so-called primary LOWS and three secondary LOWS have been charted. Of these but two, Nos. *III* and *IV*$_A$ (Chart III), were disturbances of marked intensity east of the Mississippi and both of these disturbances when last observed were moving northeastward toward Labrador rather than following the normal course eastward over the Atlantic.

With the exception of the LOWS above named both HIGHS and LOWS suffered a decrease in intensity after passing east of the Mississippi. The concentration of the HIGHS over the Missouri Valley and the Canadian Northwest, while not exceptional, gave to the month its frigid character east of the Mississippi. Not a single HIGH moved inland from the Pacific.

PRESSURE OVER THE PACIFIC AND ALASKA.

Daily reports of pressure, temperature, wind, and weather.—Daily reports of pressure, temperature, wind, and weather are received by cable and radio from two points in the Pacific and several points in Alaska. The geographical coordinates of the stations used in this discussion are as follows:

Station.	North latitude.	West longitude.	Elevation.
	° ′	° ′	*Feet.*
Midway	28 13	177 22	19
Honolulu	21 19	157 52	38
Dutch Harbor	53 55	166 30	50
Sitka	57 3	135 20	65
Eagle	64 46	141 12	834

The problem of the forecaster is how best to interpret the data received from these widely separated points, representing on the one hand subtropical areas of the mid-Pacific, and on the other sub-Arctic coastal and interior districts of Alaska. It is obvious that the individual daily pressures from these stations can have little direct bearing upon the preparation of the daily forecasts but may be of some value in their amplification or in an extension of the time beyond the present limits of 36 and 48 hours. Accidental pressure variations over continental areas have been investigated in more or less detail. In general, it is known that the amplitude of the variations increases with increase of latitude, but as between variations over sea and over land not much is known. It is the general impression, however, that the stability of the pressure over continents is greater than that over oceans.[1] The accidental variations at the two Pacific stations are small, as might be expected from their low latitude. The fluctuations at Alaskan coast stations are approximately five or six times greater than at Honolulu; at California coast stations about three times greater.

It may be that the magnitude of the accidental pressure fluctuations along coastal regions of Alaska is in some way related to the very great contrast between the air temperatures over land and sea, respectively, which obtain in that part of the globe. The records themselves afford no indication of what the relation may be, but in seeking an explanation it may be recalled that the coastal stations are on the borderland between a marine climate on the one hand and a continental climate of unusual severity on the other, and that only a slight readjustment of the prevailing weather conditions may bring the coastal station more completely under the control of oceanic influences, or, on the contrary, the control may for the time become continental. In passing from one control to the other these large pressure variations may occur. An examination of the daily weather charts for Alaska shows that the transition from high pressure to low pressure in the interior takes place sometimes slowly and again rather quickly, but generally the action at both coast and interior stations synchronizes fairly well. The following values, taken from the December, 1917, records, is an example of how quickly an interior HIGH may break down when a LOW advances from the West.

Pressure and temperature, interior and coastal Alaska, Dec. 12 to 16, 1917.

Element.	December, 1917.					Place.
	12	13	14	15	16	
Pressure (inches):						
Interior	0.88	0.88	0.04	9.98	0.10	Eagle.
Coast	0.18	9.78	9.18	9.26	9.10	Sitka.
Difference	**0.70**	**1.10**	**0.86**	**0.72**	**1.00**	
Temperature (°F.):						
Interior	−52	−46	−28	−42	−54	Eagle.
Coast	20	28	26	28	30	Sitka.
Difference	**72**	**74**	**54**	**70**	**84**	

It is seen from the above that the fall in pressure began at Eagle, the interior station, a day later than on the coast; also that it was associated with a rise of 18 degrees in temperature. With the temperature 70 to 80 degrees lower at Eagle than at Sitka the sealevel pressure will naturally be about an inch higher. After making allowance for the difference in temperature it is seen that the level of the barometer reached at the two places was nearly the same.

Accidental pressure variations.—It is one of the established facts of meteorology that a fall in the barometer which sets in over any region generally progresses from west to east, sometimes at first with a southerly component and later with a northerly component, and that a rise in the barometer succeeds a fall and in general follows the same course as did the preceding fall. Since the advent of cyclones and anticyclones from the west

[1] *Von Hann*, Lehrbuch der Meteorologie, 3d ed., Leipzig, p. 201.

or northwest is the most important known weather control for the United States, it is not strange that much study should be devoted to the detection of the first sign of the development and movement of these weather controls. The rate of movement of cyclones across the United States, on the average of the year, is about 30 miles an hour, or 720 miles in 24 hours; over the North Atlantic it is about 20 miles an hour, or but 480 miles in 24 hours; over middle Europe it is still less, and over the Pacific little is known either of the development or movement of cyclonic storms beyond the statement in Weather Bureau Bulletin A that the average annual velocity over the North Pacific east of the Alaska Peninsula is about 18 miles per hour. In the Hawaiian Islands there occur in the cold season what are known as "kona" storms, the word "kona" meaning "leeward." Since the wind in these storms blows from the southwest or leeward side of the islands, the name "kona" has been applied to them as a descriptive term. Naturally a wind from the leeward side stands out in sharp contrast to the prevailing Northeast Trades. From what little information the writer has been able to gather concerning these storms, it would seem that they are neither more nor less than cyclonic depressions, or troughs of low pressure, with a longer axis, possibly 1,000 miles in length, advancing slowly from northwest to southeast and probably dissipating long before the North American coast is reached.

Cyclones occasionally pass inland over the coast of California, south of Santa Barbara, but it is not believed that they have pursued a lengthy course over the Pacific. If cyclonic depressions moved uniformly toward the east it would be a comparatively simple matter to announce their arrival on the Pacific coast. The experience of the last 40 years, however, shows beyond the shadow of a doubt that cyclonic and anticyclonic formations are not enduring; that the form of the bounding isobars is continually changing and that the level of the barometer at the center may increase or decrease with the lapse of time, and with each change in the level of the barometer there is a corresponding change in the intensity of the formations. Under the most favorable conditions some highly-developed cyclones have been traced halfway round the globe, but these are the exceptions.

The writer has given particular attention to the pressure distribution over that part of the Pacific in which Midway Island and Honolulu, Hawaii, are situated. Midway is about 4,000 miles and Honolulu about 2,500 miles from the coast of southern California. If, therefore, we assign to cyclonic depressions a speed of 480 miles in 24 hours it would require not less than five days to pass from Honolulu to San Francisco, provided the depression held together as a definite entity for the entire distance. The probability, however, is strongly against a continuous path of 2,500 miles without change in form or intensity. Unfortunately there is no way of identifying a cyclonic depression that may have been observed at Honolulu, for example, and one which a week or 10 days later may appear on the California coast. When ship reports become more numerous than they are now it may be possible to make a positive identification.

On December 10, 1917, the barometer at Midway sank to 29.56 inches by successive falls over a period of about five days. This low level was indicative of the presence of stormy weather in that part of the Pacific. In order graphically to present the daily fluctuations of the barometer at the two Pacific stations and at several pairs of stations between Alaska and the California coast, a diagram has been prepared (not reproduced). This diagram shows that the fluctuations at the two points were in the same sense, that is, both rising or both falling, on 17 days; that they were in a different sense on 9 days, and that on 5 days there was no change at one or the other of the stations. The diagram does not show, however, any regular progression of the fluctuations from west to east. The marked fall at Midway, culminating on the 10th with a reading of 29.56 inches, did not appear in the readings at Honolulu three or four days later, although a very marked depression of the barometer on the southeastern coast of Alaska was observed on the 13th, three days later. This depression did not immediately pass inland, but seemed to develop northward along the coast on the 14th, 15th, and 16th—see the readings at Sitka in the small table on p. 607.

It might be assumed that because this depression appeared three days after the very considerable fall in the barometer at Midway, there was a direct relation between the two events. It is preferred to believe that the low pressure at Midway was a positive indication of a rather widespread barometric disturbance over that part of the ocean, with its center somewhere near the Aleutian group, and that an offshoot therefrom reached the Alaskan coast four days later.

HIGHS.

Eleven HIGHS have been plotted on Chart II, all of which originated in the Canadian Northwest and moved as shown on the chart. Two HIGHS, Nos. *II* and *VIII*, moved almost directly southward and dissipated over the Gulf States. High No. *V* moved southeastward in two branches, only one of which, the northern, endured until the Atlantic coast was reached. Three of the 11 HIGHS did not reach the Atlantic coast, and three others, Nos. *VII*, *VIII*, and *VIIIa*, suffered a material reduction in speed of movement as they neared the Atlantic. The last HIGH of the month, No. *VIII*, was characterized by central pressures of 31 inches and over, and was distinguished from the others by the fact that the level of the barometer in the LOW that preceded it did not fall below 30.05 inches until it had reached the Lake Superior region. The barometer over northern Saskatchewan and northern Manitoba, where it originated, stood at a high level with very low temperatures immediately preceding the beginning of movement of the HIGH. The movement of the HIGH became possible so soon as the pressure to the southeastward fell. This latter was an accomplished fact by the afternoon of the 26th, and on the morning of the 27th a shallow oval-shaped LOW, with central pressure 30.05 inches, was central over northern Lake Superior. The southeastward movement of the HIGH now became assured, and starting with an initial pressure of 30.80 inches it is not strange that a rise to 31 inches and over should occur during its movement over the Dakotas and the upper Mississippi Valley. The following successive pressures and temperatures at Battleford, Saskatchewan, show the rate at which the HIGH developed:

Battleford, Sask.	Pressure.	Temperature.
	Inches.	°F.
Dec. 26 1917.....p. m..	30.86	−22
Dec. 27, 1917.....a. m..	31.00	−42
Dec. 27, 1917.....p. m..	31.02	−36
Dec. 28, 1917.....a. m..	31.10	−40
Dec. 28, 1917.....p. m..	30.86	−28

This great HIGH moved eastward across the Great Lakes on the 28th and 29th and brought to eastern New York and New England the lowest winter temperatures that have been recorded since the beginning of Weather Bureau observations in 1870, the extreme minimum being reached at both New York and Boston on the morning of December 30, 1917. By this time the HIGH extended from the St. Lawrence Valley southwestward to Texas, its isobars forming a wedge-shaped configuration, with northeast to north winds in the eastern side of the wedge. Since the eastward advance of the HIGH was slow cold weather in Florida and the South Atlantic States was delayed until the morning of the 30th, and in central and southern portions of the Florida Peninsula until the morning of the 31st.

Northers in Panama.—One result of the eastward movement of this HIGH was a norther in the Canal Zone, which began December 30 and continued until January 2, 1918. Maximum velocities were attained as follows: Thirty-five miles per hour from the north on December 30, 31 miles per hour from the north on December 31, and 30 miles per hour from the north on January 1. The norther was attended by heavy rain, low temperature, and high pressure, the maximum reading 29.987 inches, being the second highest of record in the month of December.

I am indebted to Mr. R. Z. Fitzpatrick, Chief Hydrographer, Panama Canal, for the above information.

LOWS.

As before stated, but two LOWS attained the intensity of severe winter storms and for that reason they will be given special attention.

Low No. *III* evidently originated over the North Pacific, but it was not until the morning of December 6 that the center was definitely located in the northern Rocky Mountains Region. At that time pressure southward to the Mexican border was relatively low. By the afternoon of the 6th the center of low pressure was in southeastern New Mexico (see Chart III, track No. *III*). This transformation was effected by a rise in pressure in the northern and central Rocky Mountain districts and a small fall in southern districts. By the morning of the 7th the form of this barometric configuration had become an oval whose longer axis extended from Abilene, Tex., to Roswell, N. Mex. The wind circulation about the center was cyclonic and the rapidity of the pressure fall to the eastward indicated that a severe cyclonic storm was about to develop. Precipitation had not yet begun, except over Kansas and in eastern Nebraska points somewhat far distant from the center of the LOW. The LOW increased in intensity during the 24 hours following 8 a. m. December 7, and moved rapidly to southeastern Kentucky by the morning of the 8th, thence continuing in a northeasterly direction to the mouth of the St. Lawrence and passing beyond the field of observation on the 10th.

The fall in pressure near the center of this storm was unusually rapid and the barometer sank to a level of 28.92 inches by the morning of the 9th. The fall in the barometer at Washington, D. C., from 11 a. m. to 3 p. m. of the 8th was 0.51 inch, a rate that is rarely exceeded even in tropical cyclones. The following account of this storm as it passed over Lake Erie is contributed by Mr. David Cuthbertson in charge of the Weather Bureau station at Buffalo, N. Y.:

The storm appeared as a well-developed LOW over New Mexico on the 8 p. m. map of December 6. By 8 a. m. of the 8th it had moved to eastern Kentucky and increased greatly in intensity. At 8 p. m. of the 8th it was centered over eastern Lake Erie and by 8 a. m. of the 9th it had moved to the middle St. Lawrence Valley. The high-pressure area in the Northwest on the afternoon of the 7th meanwhile had moved to Texas and a new HIGH had moved in from Alberta over the upper Mississippi and Missouri Valleys and the adjacent Canadian Provinces, thus furnishing the gradient necessary for the continuance of westerly gales.

On the morning of the 8th, while the storm center was over Kentucky, northeast storm warnings were issued from the central office at 9:30 a. m., for Lakes Huron, Erie, Ontario, and southern Michigan. Snow was forecast for Saturday night and Sunday with colder weather Sunday. Snow had already been forecast on the previous day for Saturday, the 8th. In the local forecast this was amplified to "Snow, probably heavy, this afternoon and to-night; Sunday, snow and decidedly colder. Strong northeast gales becoming west to northwest to-night or early Sunday morning. Hold all shipments in common cars. Marine interests should use caution."

Besides the maps and forecast cards and the usual distribution of the forecast and warning through the local press and by telegraph, telephone, and wireless, they were given to each of the daily papers in a news article in which emphasis was placed on the necessity of preparation by all interests concerned for a severe storm as the combination of gales, snow, and severe cold held dangerous possibilities. All railroads, shippers, and marine interests who could be reached by telephone were likewise warned to take extra precautions. The storm warning was changed to "northwest" at 2 p. m. Saturday and continued "northwest" at 2 p. m. Sunday, the 9th.

Snow began falling in scattered flakes at 7:20 a. m. of the 8th and in measurable quantities at 9 a. m. Except for two intervals of two and three hours, respectively, on Sunday, the 9th, snowfall was continuous until 7:05 a. m. of Monday, the 10th. The total duration of snowfall in measurable quantities was 41 hours 40 minutes and the total depth recorded was 25 inches. A comparison with the records of other years shows that this exceeds by 2.5 inches the maximum 48-hour amount previously recorded.

As the center of the storm passed near to Buffalo and northeast winds, being from the land, seldom reach high velocity at this station, not much increase in the wind velocity was noted while the wind remained in that quarter, though reported velocities from nearby stations show that the warning was amply justified. On the shift of the wind to westerly about 10 p. m. Saturday, the velocity increased at once to 48 miles per hour and the temperature began to fall. By 11:05 p. m. the velocity had reached 74 miles and at 4:34 a. m. of Sunday, the 9th, the maximum velocity for the storm, 78 miles per hour from the west, was reached. For the 3 hours ending at 5 a. m. Sunday the wind averaged 72 miles per hour, and for the 24 hours ending at 10 p. m. Sunday the average velocity was 56 miles per hour.

The temperature fell to 6° F. by 10 a. m. Sunday, and continued from 6° to 10° during the next 24 hours. The snow was dry and consequently caused no serious interference with communication by telegraph or telephone. With one exception marine interests heeded the warnings, even to the extent of two vessels which had left the harbor returning to their anchorage. Consequently there was no loss of shipping from this port. The experience of the *McCullough*, the only vessel which ventured out, is interesting and instructive. Under the command of Capt. J. S. Neal, the *McCullough* left Buffalo Harbor at 7:45 p. m. December 8, with a cargo of coal for up the Lakes, in the midst of heavy drifting snow and with falling barometer. The wind freshened and by the time she had proceeded 50 miles the vessel was in the midst of a howling gale and blinding snow storm. It was impossible to reach shelter so, about 20 miles off Long Point, the vessel was headed into the storm and the anchors dropped. There she remained until Tuesday morning when the trip was discontinued and she returned to Buffalo. Saturday night and Sunday the waves were so high that it was impossible to pass along the deck of the vessel. Tarpaulins were torn off the hatches and the upperworks of the vessel soon became heavily coated with ice which formed as fast as the water reached them. When she returned to dock at Buffalo the vessel was so heavily loaded with ice that her bows were down a foot deeper in the water than usual for the cargo she carried.

About 9 inches of snow had already fallen when the westerly gales began at 10 p. m. Saturday. With such a depth of loose snow on the ground and the high wind velocity attained trolley traffic was soon completely demoralized by the drifting snow. Interurban and steam roads fared but little better. Even when the storm ended and the snow plows had cleared the lines, movement of freight in the yards was practically impossible until the great accumulation of snow could be hauled out.

The greatest damage from the storm centers around the delay in transportation. Many of the Lake boats detained in port will not attempt another trip and this, with the great delay in rail transportation, in view of the critical conditions existing, amounts almost to a calamity. All losses, however, which were preventable were avoided through the timely warnings of the Weather Bureau.

The following excerpt from an editorial in the Buffalo Enquirer of December 11, 1917, is a fair sample of the favorable comment of the local press on the work of the Weather Bureau in forecasting the storm:

> The severe storm which Buffalo has been experiencing since last Saturday was predicted in the forecasts sent from headquarters at Washington and supplemented by the local weather office. Early on Saturday morning warnings were issued to marine and commercial interests to use extreme caution in shipping and a general warning told of what was in store for Buffalo and vicinity.
>
> Certain results of the forecast were that millions of dollars worth of perishable goods were saved from complete destruction and untold damage was avoided by marine interests. Shippers who are obliged to depend upon weather conditions for the safe consignment of goods by rail or water are no doubt congratulating themselves that they took the advice of the Weather Bureau and thus saved themselves much trouble and loss of money for if ever the efficiency of the Weather Bureau was established it was in this particular forecast.

In a similar vein the Buffalo Evening Times said on December 12th:

> The marine and commercial interests were warned early Saturday morning by the Weather Bureau that heavy snow was to be expected in Buffalo and vicinity Saturday and Sunday, accompanied by strong gales to be followed Sunday by decidedly colder weather. Storm warnings were displayed and the marine interests were told to use extreme caution, and shippers of perishable goods were advised to hold all shipments.
>
> The people of Buffalo need not be told that the above forecast and advice was fully verified, for they experienced one of the severest storms that have passed over this vicinity in many years, and the Weather Bureau has again proven, as it has many times before, that it can be depended upon to warn the public when storms of a destructive character are about to occur.

LOW No. *IV*A (Chart III), the second case of sudden development in intensity, had a history much similar to LOW No. *III*, especially in the early part of its course. This LOW was first observed over British Columbia on the morning map of the 11th with a central pressure of 29.50 inches. It developed rapidly to the southeastward during the next 36 hours, but the rapid southward movement of HIGH No. *IV* (Chart II), appears to have divided the LOW into two portions—a northern and a southern. The southern portion filled up but the northern portion—see track No. *IV*A—moved eastward at first as a shallow cyclonic depression but during the afternoon of the 13th developed into a vigorous cyclonic storm and passed northeastward over New England on the 14th.

In this, as in the previous case, there was nothing in the surface conditions to indicate an increase in the intensity of the cyclone, except the fact that pressure fell more rapidly than usual, and this fact seems to be the only indication available to the forecaster as to an increase or diminution in the intensity of cyclonic storms. In this connection it may be worth while to refer to some of the surface phenomena of cyclonic depressions passing southeastward from the Pacific coast to the Gulf of Mexico. Our first comment is that cyclonic wind circulation in these depressions is imperfectly organized. This may be due to two considerations; first, owing to the uncertainties in barometric reductions to sealevel known to exist for the Rocky Mountains and Plateau regions the center of the LOW may not have been placed in its proper geographic position; and second, the observing stations are widely scattered; some are separated from each other by high mountains, others are situated in valleys or depressions which largely control the wind direction. It is, therefore, to be expected that the mapped circulation about a LOW in that region will be more or less imperfect. On the other hand, when the wind shifts, or backs, to north the effect of irregularities in topography disappear—there is almost absolute uniformity in the direction of the winds, all being from a northerly quarter, and the force is much greater than from any other quarter.

Our second comment is that the movement of a depression over the Rocky Mountains region seems to be almost wholly dependent on the "force" or "driving power" of the HIGH to the northward; and the strength of the HIGH seems to be proportional to the depth of the depression in its front. In other words, the greater the contrast between temperature and pressure (I say temperature and pressure advisedly) the greater is the speed with which the depression is forced toward the southeast. This point has already been touched on in the account of the two LOWS above mentioned, and it has also been pointed out that of the surface winds northerly winds are uniformly the stronger. From these facts it seems reasonable to infer that the superior force of the northerly winds, largely if not wholly a gravitational force, literally swept that portion of the depression immediately in contact with the surface, far to the southeastward: that there remains a disturbance in the upper levels which may or may not be continuous with the remnant on the surface appears quite likely, and this view is strengthened by the sequence of events attending LOW No. *IV*A (Chart III). In this case the level of the barometer over British Columbia just after the LOW passed inland was 29.50 inches; when it reached Colorado the level at the center had risen to 29.74 inches. Then began the aweeping movement in the rear, due to the superior force or driving power of high pressure and low temperature in Montana and to the northward. As a result in 12 hours the center of low pressure apparently had been separated into two parts; one of which was over Texas with a central pressure of 29.86 inches, an increase in central pressure of 0.36 inch; the second part being over eastern Missouri with a central pressure of 30.14 inches, an increase of 0.64 inch. In 24 hours the southern depression had disappeared and the northern depression was central over Indiana with its lowest pressure at 30 inches, and singularly the precipitation in connection with it was confined to the northern and western quadrants, a condition not usually occurring in depressions east of the Mississippi. The surface winds were light, but the circulation was truly cyclonic. Temperature was low and the ground snow covered, yet the barometer fell rapidly during the 13th, the wind increased in force, and a severe winter storm developed.

It is difficult to explain this marked increase on the basis of surface conditions, and indeed it is not easy to explain it from upper-air conditions without indulging in more or less speculation. It does seem, however, that the circumstances recited above lead to the inference that the seat of energy of the LOW does not rest on the surface, but rather that there is a column of warmer air whose upper limit may extend to 5 kilometers, and possibly higher, in which cyclonic depressions are carried along; that this warmer upper current is underrun on its western margin by a cold, dry current from the north or northwest which does not extend upward much above 3 kilometers. While these altitudes are approximate they are based, in part, on the evidence afforded by kites and mountain observations as to the relative shallowness of the northerly winds that flow over the Plains States directly east of the Rocky Mountains. The existence and height of a southwest current is inferred from the movement of upper clouds at stations in the Southwest, particularly New Mexico, Texas, Arkansas, and Oklahoma, supplemented by kite observations at Mount Weather, Va., and Drexel, Nebr. Much critical examination of the movement of cyclones and anticyclones is yet required before definitive statements can be made.

WARNINGS.

Storm warnings were issued as follows: On the Great Lakes, or some portion of them, on December 2, 8, 9, and 17; on the Atlantic coast, or some portion of it, December 1, 6, 8, and 13; on the Middle Gulf coast on December 7 and 11. Cold-wave warnings were issued for some part of the Washington Forecast District on December 7, 8, 9, 13, 14, 22, 23, 24, 25, 27, 28, and 29. Warnings of frost and freezing temperature in the truck regions of the South were issued, in connection with the daily forecasts, on numerous dates. Reports of activities at other forecast centers follow.

WARNINGS FROM OTHER DISTRICTS.

Chicago, Ill., forecast district.—The weather during December, 1917, over most of the Chicago forecast district was abnormally cold with frequent precipitation, practically all of which was in the form of snow. Periods of temperature above normal were short and infrequent, and cold weather persisted throughout practically all sections.

The first cold-wave warnings of the month were issued on the morning of December 6 for North Dakota and eastern Montana in connection with an area of high pressure over Saskatchewan. By the morning of the 7th this area had assumed the proportions of a well-marked cold wave, preceded as it was by a rapidly deepening depression central over western Texas. Warnings were therefore extended to all the remaining portions of the district, except the extreme eastern sections, where at that time, the temperatures were already low. During the day, the disturbance over Texas moved northeastward increasing in intensity and causing unusually heavy falls of snow in the southern portions of Missouri and Illinois. It was followed by extreme cold for so early in the season, record low temperatures for December being reported at some points on the morning of the 9th. All warnings issued for this cold wave were fully verified.

Another cold high area appeared over Alberta on the morning of the 8th, and moved rapidly southeastward, causing a continuation of the cold weather over practically the entire district. As the temperatures were then already abnormally low over most sections, no warnings were issued during the passage of this HIGH over the district, except on the evening of the 8th to Cheyenne, Wyo., Rapid City, S. Dak., western Nebraska and western Kansas, and on the morning of the 9th to southeastern Kansas. These warnings were partially verified.

The weather map on the morning of the 11th indicated the development of a low pressure area over eastern North Dakota extending southwestward and then northwestward to a deep depression in British Columbia, with severe cold and high pressure in the Canadian Northwest. By evening the pressure over the latter section had increased considerably and, anticipating its movement eastward and southward in the rear of the crescent-shaped trough which had deepened and moved southward during the day, warnings were issued to Wyoming and northwestern Montana. The temperatures at that time were much below 0°F. over North Dakota and the balance of Montana. The 8 a. m. map of the 12th indicated and warnings were sent to all points as far south as Kansas and northwest Missouri and as far east as southeast Wisconsin; and on the basis of the 1 p. m. special observations, they were extended to include the remainder of the eastern portion of the district. All warnings in connection with this cold wave were verified with the exception that in eastern and extreme southern Illinois a verifying temperature fall was not reached, although readings close to 0° were reported.

The last cold wave of the month first appeared at Edmonton on the evening of December 22, and warnings were then issued for North Dakota and eastern Montana. During the 23d a crescent-shaped depression formed in front of this high-pressure area with a trough reaching from western Lake Superior southwestward and westward across the middle Rockies to the Plateau Region, thus producing ideal conditions for an extensive cold wave. Warnings for severe cold with strong winds were issued successively—from the 8 a. m. map, 1 p. m. special observations, and the 8 p. m. map—for all regions likely to be affected within the next 24 to 36 hours, so that by the morning of the 24th, the entire district east of the Rocky Mountains had been covered with the exception of eastern Illinois, where the cold was not expected to be severe owing to the high temperature prevalent during the 23d. Although the temperature in Kansas and Missouri did not reach as low a point as expected, the cold was severe over the northern and central portions of the district and the warnings fully justified.

On the morning of the 25th, the pressure had increased to a reading of 30.82 inches at Moorhead, Minn., with indications of a reinforcement over Saskatchewan and Manitoba, but owing to a development of a low-pressure area over the middle Plains States during the 26th, the southward movement of the reinforced cold was delayed until the night of the 26th. The morning map of the 27th showed intense cold in the Canadian Northwest with the remarkably high barometric pressure of 31 inches at Battleford. These extreme conditions advanced slowly eastward and southward during the 27th and 28th and were preceded by warnings for severe cold well in advance, practically all of which were verified. At many points in the Middle West, the lowest December temperatures of record were reported, and on the 28th barometric readings as high as 31.18 inches were recorded over the Dakotas and adjoining sections.

Temperatures considerably below normal prevailed over the district east of the Rocky Mountains until the end of the month, although a marked moderation had set in over western sections by the evening of the 31st.—*Ernest H. Haines, Meteorologist.*

New Orleans, La., forecast district.—Frost or freezing weather warnings were issued for the southern portion of this district on December 6, 10, 13, 14, 25, 28, 29, 30, and 31. The frosts or freezing temperatures occurred as forecast, and neither condition occurred without warnings being issued.

Cold waves were of frequent occurrence and warnings were issued as follows:

December 7, 9:45 a. m., cold wave—Oklahoma, western Texas, and the northern portion of eastern Texas; 2:30 p. m., for southern Texas; and 9:30 p. m., for southern Texas and eastern and southern Louisiana. The warnings were fully justified.

December 11, 1:30 p. m., cold wave southeastern Louisiana; was justified.

December 12, 2 p. m., cold wave northwest Arkansas, Oklahoma, western Texas, and the northwestern portion of eastern Texas; 9:30 p. m., Oklahoma and Texas except on the immediate coast, and at 9:55 a. m. of the 13th for southeastern Louisiana. Intense cold prevailed nearly to the coast and the warnings were justified.

December 23, 9:45 p. m., cold wave, Oklahoma, northern portion of western Texas, northwestern portion of eastern Texas, and northwestern portion of Arkansas; on

the 24th, 9:50 a. m. and 2 p. m., for Arkansas, Oklahoma, Texas except the immediate coast, and northwestern Louisiana; at 9:30 p. m., for Arkansas, Louisiana except southeastern portion, and for the eastern and southern portions of eastern Texas; on the 25th, 10:45 a. m., for the Texan coast and Louisiana except northwestern portion. A decided fall in temperature occurred but the high-pressure area did not follow the anticipated course toward the southeast and verifying temperatures were recorded at only a few stations.

Intense weather conditions were shown on the 8 a. m. weather map of December 27, and their progress southeastward over the district, with exceptionally severe weather, was forecast.

The cold wave, of unusual severity for December, moved southward, breaking records of long standing in some localities. It brought temperatures of about 0° F. or below in the Texas Panhandle and Oklahoma; 10° to 14° in northern Texas; and 20° to 26° in the southern portion; 0° to 8° in northern and 8° to 12° in southern Arkansas; 10° to 14° in northern and 12° to 19° in southeru Louisiana. At New Orleans the minimum temperatnre was 19°, the lowest of record at this station.

The warnings and advices relative to protective measures which should be taken were generally followed and much loss to vegetation and live stock prevented. Although the harvesting of matured crops was pushed, the loss of vegetables in the fields, for which no protection was provided, exceeds $1,000,000. Only about half of the people heeded the warning to drain their water pipes, and the pipes in more than 3,000 residences were burst by by the freeze.

Storm warnings issued on December 7 were verified. No general storm occurred without warning.

Fire-weather warnings were issued on the 7th, 18th, and 24th and were justified.—*I. M. Cline, District Forecaster.*

Denver, Colo., forecast district.—December, 1917, was unusually dry and mild in this district, due to a succession of cyclonic areas which passed eastward along the northern storm tracks. At Modena on the 19th and at Phoenix and Modena on the 29th higher temperatures were reported than ever previously recorded at those stations so late in December. The district was notably free from storms. No cold waves occurred, except on the eastern slope, where there were rapid alternations of temperature, especially in eastern Colorado from the 7th to the 14th, and in the early part of the third decade when the weather was under the influence of anticyclones that moved southward from Alberta.

Cold-wave warnings were issued for portions of eastern Colorado on the 7th, 8th, 9th, 11th, 12th, 13th, 23d, and 24th, and for eastern New Mexico on the 7th, 9th, and 12th. The warnings were generally fully verified, except for eastern Colorado for the 24th and 25th. However, temperatures were 20° to 30° lower in eastern Colorado on the 24th and were close to 0° in portions of eastern Colorado on the 25th. Frost warnings were issued for south-central Arizona on several days during the fore part of the month, and frosts were frequent in that portion of the State, with a killing frost near Yuma on the 8th.—*Frederick W. Brist, Assistant Forecaster.*

San Francisco, Cal., forecast district.—Storms moved eastward from the North Pacific with great regularity during December, 1917; but with the exception of the storm of the 25th, which passed inland along the Canadian boundary, their passage was through northern British Columbia. The storm movement at so high a latitude at this season of the year gave almost continual rain or snow in Washington and more than the usual number of days with precipitation in Oregon and Idaho, and very light precipitation in California and Nevada. In fact, drought conditions prevail in the two latter States.

Storm warnings were issued along the Washington and Oregon coasts on the 15th, 16th, 21st, 23d, 25th, 28th, and 31st, and along the California coast from Point Reyes northward on the 25th. In most cases they were verified, and it is believed that they were justified in every instance

Areas of high pressure prevailed almost continually over the central and southern plateau region causing severe frosts almost daily during the first half of the month in California. While the temperature in the citrus belts fell below freezing on many nights, it did not reach a sufficiently low point to do any material damage.

Unusually high temperatures occurred in Idaho and Nevada on the 19th, and in portions of Washington, Oregon and Idaho on the 29th, when previous records for December were equalled or exceeded. The warm weather on the 29th caused a rapid melting of the snow in the mountains in western Washington, resulting in high rivers and some damage from floods.

This is probably the driest season in California since records have been kept, and there is less snow in the mountains than ever before known at this time of the year. Only isolated peaks are snow covered and the great area above 5,000 feet, at this season usually covered with several feet of snow, is now bare.—*G. H. Willson, District Forecaster.*

HURRICANES OF 1917.

By CHARLES A. DONNEL, Meteorologist.

[Dated: Weather Bureau, Washington, D. C., Feb. 3, 1918.]

Fewer storms than usual, of tropical origin, occurred during the year 1917. In fact only one disturbance that could be classed as a hurricane of the first magnitude viz, September 22–30, came within the field of our observations. However, it has seemed proper to include four storms in the present category, and their paths have been traced on Chart X (XLV—121) of this issue of the MONTHLY WEATHER REVIEW.

Storm of August 9.—Information concerning this storm is extremely meager. What at the time was believed to be a secondary center of a barometric depression moving eastward near the mouth of the St. Lawrence River appeared off the North Carolina coast. Later advices seem to disclose that this storm was of tropical origin, having formed east of the Virgin Islands and passing thence northwestward to the position charted on August 9.

Storm of September 4.—On September 4 a storm appeared south of the Bermuda Islands as shown by the weather report from Hamilton. The pressure was 29.46 inches with a wind of gale force and rain. The center of the disturbance passed to the eastward and northward of the islands some time between 12 o'clock noon and 4 p. m. the same date. No further facts in reference to this storm have been received.

Storm of September 13–18.—The second tropical storm of September made its first appearance as a definite disturbance on the morning of September 13 over eastern Cuba. During the following 24 hours the center moved northward to a position off the eastern coast of Florida. From that point the storm advanced northeastward and by the night of September 17–18 was off Cape Cod. It continued its northeastward movement and passed beyond Newfoundland on September 20.

Storm of September 22–30.—This storm may be classed as a hurricane of the first magnitude. It first showed true cyclonic characteristics on September 22 south of Haiti, advancing thence in a general west-northwesterly direction to a position off the mouth of the Mississippi River whence it recurved sharply to the northeastward and entered the United States near Pensacola, Fla. Dissolution began soon after the storm struck the land and by the morning of September 30 the remnants had disappeared over southeastern Georgia. Articles descriptive of this hurricane appear in the REVIEWS for September and October, 1917. The few additional facts that have come to hand since the articles referred to were prepared, serve to furnish evidence as to the hurricane's great intensity throughout virtually its entire existence. The center of the track crossed Jamaica and great destruction was caused on that island, the banana industry having been almost wiped out. Mr. O. L. Fassig, Meteorologist, U. S. Weather Bureau, who visited the Isle of Pines shortly after the passage of the hurricane there, states that the town of Nueva Gerona was devasted, many of the staunchest structures in the town having been leveled. Three apparently reliable barometer readings at that point indicated a minimum of 27.70 inches about 1 p. m. of September 25. In the Pinar region of western Cuba orchards and other crops were ruined. It is thought that a special report by Mr. Fassig on this storm will be prepared later on.

SECTION IV.—RIVERS AND FLOODS.

RIVERS AND FLOODS, DECEMBER, 1917.

By ALFRED J. HENRY, Meteorologist in Charge.

[Dated: River and Flood Division, Weather Bureau, Jan. 23, 1918.]

During December, 1917, the precipitation east of the Rocky Mountains was largely in the form of snow and the temperature was abnormally low. As a result rivers in northern districts became icebound, and heavy ice formed on Southern rivers, which in conjunction with low stages caused a complete suspension of traffic in many rivers, the Tennessee in particular.

The Mississippi at St. Louis, Mo., reached the lowest level since the beginning of observations, on December 13, when a stage of 2.95 feet below gage-zero was recorded, or 0.4 foot below the previous lowest reading. At the close of the month heavy ice was running at St. Louis, although the stream had been blocked by ice at Hannibal for some days previous.

Heavy rains and warm weather combined to produce flood stages on the rivers of Washington and Oregon during the last third of the month. The first flood on the Willamette crested at Portland, Oreg., on the 20th, and there was a second crest stage on the 31st. On the closing days of the month the small streams of western Washington were in flood. Railroad traffic was interrupted and some loss to bridges was sustained. The details of the flood in the lower Columbia River are shown in Table 1.

Hydrographs for typical points on several principal rivers are shown on Chart I. The stations selected for charting are Keokuk, St. Louis, Memphis, Vicksburg, and New Orleans, on the Mississippi; Cincinnati and Cairo, on the Ohio; Nashville, on the Cumberland; Johnsonville, on the Tennessee; Kansas City, on the Missouri; Little Rock, on the Arkansas; and Shreveport, on the Red.

TABLE 1.—*Flood stages in the Columbia drainage basin during December, 1917.*

River.	Station.	Flood stage.	Above flood stages—dates.		Crest.	
			From—	To—	Stage.	Date.
		Feet.			*Feet.*	
Columbia	Vancouver, Wash	15	20	20	15.2	20
Do	do	15	22	23	15.3	22
Do	do	15	29	(†)	17.5	31
Willamette	Eugene, Oreg	10	24	24	11.5	24
Do	Albany, Oreg	20	25	25	20.5	25
Do	Salem, Oreg	20	20	21	24.0	20
Do	Oregon City, Oreg	10	18	(†)	14.5	21
Do	Portland, Oreg	15	19	24	19.7	20
Do	do	15	27	(†)	19.3	31
Santiam	Jefferson, Oreg	10	14	14	10.5	14
Do	do	10	18	20	16.0	19
Clackamas	Cazadero, Oreg	12	18	20	18.0	19
Yamhill	McMinnville, Oreg	35	20	20	38.7	20

† Continued into January, 1918.

MEAN LAKE LEVELS DURING DECEMBER, 1917.

By UNITED STATES LAKE SURVEY.

[Dated: Detroit, Mich., Jan. 7, 1918.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.*			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during December, 1917:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sealevel at New York	602.16	580.80	572.67	246.45
Above or below—				
Mean stage of November, 1917	−0.30	−0.34	−0.30	−0.24
Mean stage of December, 1916	−0.97	+0.23	+1.15	+1.08
Average stage for December, last 10 years	−0.13	−0.80	+1.09	+1.09
Highest recorded December stage	−0.97	−1.78	−0.86	−1.16
Lowest recorded December stage	+0.96	+1.80	+1.81	+3.02
Average relation of the December level to—				
November level	−0.2	−0.1	−0.1	−0.2
January level	+0.3	+0.2	±0.0	±0.0

* Lake St. Clair's level: In December, 575.53 feet.

SECTION V.—SEISMOLOGY.

SEISMOLOGICAL REPORTS FOR DECEMBER, 1917.

W. J. HUMPHREYS, Professor in charge of Seismological Investigations.

[Dated: Weather Bureau, Washington, D. C., February 2, 1918.]

TABLE 1.—*Noninstrumental earthquake reports, December, 1917.*

Day.	Approximate time, Greenwich Civil.	Station.	Approximate latitude.	Approximate longitude	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		CALIFORNIA.								
1917.	*H. m.*		° ′	° ′			*M. s.*			
Dec. 8	9 45	Calexico	32 41	115 30	4	1	5	Rumbling...	Doors and dishes rattled	Ivan R. Ralston.
20	8 23	Barrett Dam	32 40	116 44	3	1		None		Lorenzo Watts.
		Brawley	33 00	115 31	4	1	5	Rumbling...		M. D. Witter.
		Calexico	32 41	115 30	3	1	5	Rumbling...		H. M. Rouse.
		Calexico	32 41	115 40	4	2	5	None		Ivan R. Ralston.
		IDAHO.								
12	12 00	Ashton	44 04	111 29	2	1	1 0	None		A. M. Slatery.
		Chesterfield	42 53	111 52	5	1	3	None		Charles S. West.
		Fort Hull	43 09	112 10	3	1	2	None		C. H. Southworth.
		Idaho Falls	43 29	112 01	2	1		None		Anna Lee Bridges.
		Irwin	43 25	111 20	5	1	20	None		Lula Sanders.
		Pocatello	42 52	112 29	3	1		None		A. R. Teeple.
		Sugar	43 52	111 44	2	1		None		Hattie Gearhart.
		WYOMING.								
12	11 50	Bedford	42 54	110 58	5	1	30	Rumbling...		Charles G. Heiner.

TABLE 2.—*Instrumental reports, December, 1917.*

[Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.

[For significance of symbols see REVIEW for July, 1917, p. 373.]

Alaska. *Sitka. Magnetic Observatory.* U. S. Coast and Geodetic Survey. J. W. Green.

Lat. 57° 03′ 00″ N.; long., 135° 30′ 06″ W. Elevation, 15.2 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants: {E V 10, T_0 16; N V 10, T_0 15}

Date.	Character.	Phase.	Time.	Period, T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	*μ*	*μ*	*km.*	
Dec. 21	.....	eP_E	17 56 46	.....	.....	.....	.....	
		eN	17 58 03	.....	.....	.....	.....	
		eS_E	17 59 16	.....	.....	.....	.....	
		M_E	18 00 01	.....	670	.....	.....	
		eL_E	18 01 02	18	.....	.....	.....	
		M_E	18 07 22	18	650	.....	.....	
		M_N	18 07 49	14	.....	950	.....	
		C	18 12 ..	12	.....	.....	.....	
		F	20 18 ..	.....	.....	.....	.....	
21	.....	e_N	20 56 16	.....	.....	.....	.....	No phases.
		e_E	20 57 04	.....	.....	.....	.....	
		M_N	21 03 28	.....	.....	60	.....	
		F	21 35 ..	.....	.....	.....	.....	
26	.....	e_N	13 35 36	.....	.....	.....	.....	No phases. Driving clock on E-component had stopped.
		M_N	13 46 ..	11	.....	20	.....	
		F	13 58 ..	.....	.....	.....	.....	
28	.....	.....	.....	.....	.....	.....	.....	Imperfect record. Impossible to determine any of the phases of earthquake on this date.
29	.....	eP_N	22 59 30	3	.....	.....	.....	E-component not recording.
		S_N	23 07 06	10	.....	.....	.....	
		eI_N	23 15 40	26	.....	.....	.....	
		M_N	23 20 20	15	.....	600	.....	
		C	23 26 ..	10	.....	.....	.....	
		F	23 50 ..	.....	.....	.....	.....	

Arizona. *Tucson. Magnetic Observatory.* U. S. Coast and Geodetic Survey. F. P. Ulrich.

Lat., 32° 14′ 48″ N.; long., 110° 50′ 06″ W. Elevation, 769.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants: {E V 10, T_0 19; N V 10, T_0 19}

Date.	Character.	Phase.	Time.	Period, T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	*μ*	*μ*	*km.*	
Dec. 21	.....	eP_E	18. 01 24	6	.....	.....	.....	
		eS_E	18 07 34	.....	.....	.....	.....	
		eL_E	18 13 00	14	.....	.....	.....	
		M_E	18 25 59	13	20	.....	.....	
		F_E	19 08 ..	.....	.....	.....	.....	
26	.....	e_E	5 31 06	.....	.....	.....	.....	
		e_N	5 31 11	.....	.....	.....	.....	
		M_E	5 37 07	7	10	.....	.....	
		M_N	5 37 50	8	.....	10	.....	
		F	5 51 ..	.....	.....	.....	.....	
28	.....	P	21 21 57	4	.....	.....	.....	
		eL_N	21 34 30	14	.....	.....	.....	
		eL_E	21 36 29	12	.....	.....	.....	
		M_E	21 42 51	10	10	.....	.....	
		M_N	21 45 30	11	.....	20	.....	
		F	22 04 ..	.....	.....	.....	.....	
29	.....	eP_E	22 55 18	8	.....	.....	.....	
		eP_N	22 55 22	8	.....	.....	.....	
		eS_E	22 59 30	10	.....	.....	.....	
		eS_N	22 59 36	12	.....	.....	.....	
		L	23 02 12	20	.....	.....	.....	
		M_E	23 03 ..	13	6,260+	.....	.....	Movement limited by brushes.
		M_N	23 06 ..	11	.....	6,000+	.....	
		C	23 10 ..	14	.....	.....	.....	
30	.....	F	1 15 ..	10	.....	.....	.....	

TABLE 2.—*Instrumental reports, December, 1917*—Continued.

California. *Berkeley. University of California.*

Lat., 37° 52′ 16″ N.; long., 122° 15′ 37″ W. Elevation, 85.4 meters.

(*See* Bulletin of the Seismographic Stations, University of California.)

California. *Mount Hamilton. Lick Observatory.*

Lat., 37° 20′ 24″ N.; long., 121° 38′ 34″ W. Elevation, 1,281.7 meters.

(*See* Bulletin of the Seismographic Stations, University of California.)

California. *Point Loma. Raja Yoga Academy.* F. J. Dick.

Lat., 32° 43′ 03″ N.; long., 117° 15′ 10″ W. Elevation, 91.4 meters.

Instrument: Two-component, C. D. West seismoscope.

Date.	Character.	Phase.	Time.	Period, T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Dec. 3					50	50		Tremors recorded during the 24 hours ending 16h 00m on dates given.
5					50	50		
6					50	100		

California. *Santa Clara. University of Santa Clara.* J. S. Ricard, S. J.

Lat., 37° 26′ 36″ N.; long., 121° 57′ 63″ W. Elevation, 27.43 meters.

(*See* Record of the Seismographic Station, University of Santa Clara.)

Colorado. *Denver. Sacred Heart College.* Earthquake Station. A. W. Forstall, S. J.

Lat., 39° 40′ 36″ N.; long., 104° 58′ 54″ W. Elevation, 1,655 meters.

Instrument: Wiechert 80 kg., astatic, horizontal pendulum.

Instrumental constants .....

Date.	Character.	Phase.	Time.	Period, T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Dec. 12	II_F	L_N	12 20 ..					P and S waves not discernable.
		L_E	12 30 ..					
		M_N	(?)					
		M_E	12 20 40	4–6		*4,000		
		F_E	12 22 ..					
		F_N	12 23 ..					
21	I_F	L_E	18 12 ..					P and S waves not discernable.
		L_N	18 13 ..					
		M	18 14 ..	10–13	*1,000	*1,000		
		F_N	18 20 ..					
		F_E	18 21 ..					
27								Very strong activity at intervals.
28								
28	I_F	L	21 38 ..	0.5				
		F	21 50 ..					
29	III_F	P	22 58					
		L	23 02 ..	5–6	*10,000	*8,500		
		M_E	23 08 ..	7				
		M_N	23 10 ..	5				
		C_E	23 15 ..					
		C_N	23 19 ..					
		F_E	23 29 ..					
		F_N	23 30 ..					

* Trace amplitude.

District of Columbia. *Washington. U. S. Weather Bureau.*

Lat., 38° 54′ 12″ N.; long., 77° 03′ 03″ W. Elevation, 21 meters.

Instrument: Marvin (vertical pendulum), undamped. Mechanical registration.

	V	T_0
Instrumental constants..	110	6.4

Date.	Character.	Phase.	Time.	Period, T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Dec. 12		S?	11 04 23					
		L?	11 06 19					
		F	11 15 ..					
21		P	18 03 35				5,600	
		S	18 10 50					
		SR1	18 13 20					
		L	18 14 42	20				
		L	18 20 15	20				
		F	19 45 ..					
21		P?	21 01 15					
		S	21 08 23					
		L	21 18 25	16				
		F	22 00 ..					
23		eL	14 38 ..					
		L	14 45 ..					
		F	15 00 ..					
23		?e	15 59 20					
		S	16 04 10					
		L	16 05 45					
		L	16 09 30					
		F	16 30 ..					
26		e	5 30 ..					
		L	5 35 ..					
		F	5 50 ..					
26		eL	13 58 ..					
		F	14 30 ..					
28		P	21 23 21				4,820	
		S	21 29 53					
		SR1	21 33 21					
		L	21 35 ..					
		L	21 40 15	20				
		F	21 45 ..					
29		P	22 56 35				3,040	
		S	23 01 21					
		L?	23 03 ..					
		L	23 05 20	28				
30		F	00 30 ..					

District of Columbia. *Washington. Georgetown University.* F. A. Tondorf, S. J.

Lat., 38° 54′ 25″ N.; long., 77° 04′ 24″ W. Elevation, 42.4 meters. Subsoil: Decayed diorite.

Instruments: Wiechert 200 kg. astatic horizontal pendulums, 80 kg. vertical.

		V	T_0	ε
Instrumental constants..	E	165	5.4	0
	N	143	3.2	0
	Z	*80*	*3.0*	*0*

Date.	Character.	Phase.	Time.	Period, T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Dec. 12	III	e	11 00 09					e doubtful.
		S	11 04 46					
		eL	11 06 03					
		F	11 16 ..					
21	IIIu	e	18 03 23					Microseisms present, but not heavy. P and S waves on Mainka 7m 14s.
		S	18 10 46					
		L_N	18 20 13	21				
		L_E	18 20 13	20				
		M_N	18 24 59		*2,000			
		M_E	18 26 27		*2,900			
		F	19 45 ..					
				VERTICAL.				
		e_Z	*18 03 43*					*S waves not discernible.*
		L_Z	*18 21 09*	*20*				*No distinct main.*
		F_Z	*19 18* ..					
21		e_N?	21 05 56					Heavy microseisms.
		e_E?	21 06 10					
		eL?	21 18 12					S waves in nowise discernible.
		F	22 09 ..					
23		e?	15 59 00					Heavy microseisms present.
		L	16 06 02	17				
		F	16 25 ..					

* Trace amplitude.

TABLE 2.—*Instrumental reports, December, 1917*—Continued.

Date.	Character.	Phase.	Time.	Period, T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
District of Columbia. *Washington. Georgetown University.* F. A. Tondorf, S. J.—Continued.								
1917. Dec. 26	.....	e_E?....	*H. m. s.* 5 30 00	*Sec.*	*μ*	*μ*	*km.*	Gram very difficult.
		e_E?....	5 30 04	.....	.....	.....	.....	Microseisms present.
		S_N?....	5 34 29	.....	.....	.....	.....	
		S_E?....	5 34 41	.....	.....	.....	.....	
		eL?....	5 35 24	.....	.....	.....	.....	
		F.....	5 52 ..	.....	.....	.....	.....	
26	.....	.....	.....	.....	.....	.....	.....	Quake between 13h and 14h et postea lost in changing sheets.
28	.....	e.....	21 23 28	.....	.....	.....	.....	Heavy microseisms present.
		eL.....	21 35 00	.....	.....	.....	.....	
		L.....	21 41 16	14	.....	.....	.....	Sinusoidal waves from 21h 49m to 22h. F waves lost in microseisms.
	II–III	iP_N....	22 56 28	.....	.....	.....	.....	Heavy microseisms.
		iP_E....	22 56 30	.....	.....	.....	.....	
		S_W.....	23 01 16	.....	.....	.....	.....	F uncertain.
		S_E.....	23 01 18	.....	.....	.....	.....	
		eL.....	23 03 07	17	.....	.....	.....	
		M_N....	23 10 17	.....	.....	*1,900	.....	
		M_E....	23 12 27	.....	*2,200	.....	.....	
30		F.....	1 (ca)	.....	.....	.....	.....	
29	.....	iP_Z....	*22 56 31*	VERTICAL.	.....	.....	.....	*S waves not quite as certain as P waves.*
		S_Z.....	*23 01 39*	.....	.....	.....	.....	
		L_Z.....	*23 05 44*	*39*	.....	.....	.....	
30		F_Z.....	*1 00* (ca)	.....	.....	.....	.....	*No distinct main.*

* Trace amplitude.

Hawaii. *Honolulu. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Frank Neumann.

Lat., 21° 19′ 12″ N.; long., 158° 03′ 48″ W. Elevation, 15.2 meters.

Instrument: Milne seismograph of the Seismological Committee of the British Association, E–W component.

Instrumental constant....T_0 18.6

1917. Dec. 3	.....	e.....	*H. m. s.* 4 56 12	*Sec.*	*μ*	*μ*	*km.*	
		M.....	5 04 00	19	100	.....	.....	
		F.....	5 22 ..	.....	.....	.....	.....	
9	.....	eL.....	2 44 00	.....	.....	.....	.....	
		M.....	2 45 00	18	100	.....	.....	
		F.....	2 48 ..	.....	.....	.....	.....	
9	.....	e.....	16 11 48	.....	.....	.....	.....	
		M.....	16 14 00	19	100	.....	.....	
		F.....	16 27 ..	.....	.....	.....	.....	
11	.....	e.....	13 32 12	.....	.....	.....	.....	
		M.....	13 36 48	20	100	.....	.....	
		F.....	13 44 ..	.....	.....	.....	.....	
13	.....	e.....	3 18 18	.....	.....	.....	.....	
		M.....	3 30 36	19	100	.....	.....	
		F.....	3 32 ..	.....	.....	.....	.....	
15	.....	eL.....	16 03 42	.....	.....	.....	.....	Phases uncertain on account of wind tremors.
		M.....	16 08 00	18	100	.....	.....	
		F.....	16 10 ..	.....	.....	.....	.....	
17	.....	e.....	19 27 06	.....	.....	.....	.....	Observer in the room at the time.
		M.....	19 28 00	20	300	.....	.....	
		F.....	19 31 ..	.....	.....	.....	.....	
21	.....	eP.....	18 03 18	.....	.....	.....	.....	Seismograph not working properly. Impossible to determine phases.
21	.....	eL.....	21 09 00	.....	.....	.....	.....	
		M.....	21 09 24	11	900	.....	.....	
		C.....	21 12 00	.....	.....	.....	.....	
		F.....	21 18 ..	.....	.....	.....	.....	

Kansas. *Lawrence. University of Kansas.* Department of Physics and Astronomy. F. E. Kester.

Lat., 38° 57′ 30″ N.; long., 95° 14′ 58″ W. Elevation, 301.1 meters.

Instrument: Wiechert.

	V	T_0	*ε*
Instrument constants.. E	177	3.4	4:1
Instrument constants.. N	205	3.4	4:1

(Report for December, 1917, not received.)

Maryland. *Cheltenham. Magnetic Observatory.* U. S. Coast and Geodetic Survey. George Hartnell.

Lat., 38° 44′ 00″ N.; long., 76° 50′ 30″ W. Elevation, 71.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

	V	T_0
Instrumental constants.. E	10	33
Instrumental constants.. N	10	25

1917. Dec. 12	.....	e_E.....	*H. m. s.* 11 04 40	*Sec.*	*μ*	*μ*	*km.*	Very faint. N component too disturbed by wind tremors to distinguish any seismic motion.
		F.....	11 08 ..	.....	.....	.....	.....	
21	.....	eP_E...	18 03 36	2	.....	.....	.....	
		S_E....	18 10 58	4	.....	.....	.....	
		S_N....	18 11 06	4	.....	.....	.....	
		eL_N...	18 20 30	17	.....	.....	.....	
		eL_E...	18 20 46	17	.....	.....	.....	
		M_E....	18 27 08	15	600	.....	.....	
		M_N....	18 27 57	15	.....	580	.....	
		C.....	18 32 00	.....	.....	.....	.....	
		F.....	19 02 ..	.....	.....	.....	.....	
26	.....	e.....	5 33 00	.....	.....	.....	.....	
		M_N....	5 38 38	10	.....	10	.....	
		M_E....	5 39 ..	10	10	.....	.....	
		F.....	5 54 ..	.....	.....	.....	.....	
28	.....	eP_E...	21 23 58	.....	.....	.....	.....	
		eS_N...	21 30 57	.....	.....	.....	.....	
		eS_E...	21 31 17	.....	.....	.....	.....	
		eL_E...	21 41 37	12	.....	.....	.....	
		eL_N...	21 41 48	12	.....	.....	.....	
		M_E....	21 46 43	17	200	.....	.....	
		M_N....	21 53 25	12	.....	140	.....	
		C.....	22 01 ..	.....	.....	.....	.....	
		F.....	22 29 ..	.....	.....	.....	.....	
29	.....	eP_N...	22 56 27	4	.....	.....	.....	
		eP_E...	22 56 32	4	.....	.....	.....	
		S.....	23 01 27	8	.....	.....	.....	
		eL_E...	23 04 25	18	.....	.....	.....	
		eL_N...	23 04 50	14	.....	.....	.....	
		M_E....	23 10 27	14	450	.....	.....	
		M_N....	23 15 08	12	.....	100	.....	
		C.....	23 28 ..	.....	.....	.....	.....	
30		F.....	00 09 ..	.....	.....	.....	.....	

TABLE 2.—*Instrumental reports, December, 1917*—Continued.

Massachusetts. *Cambridge. Harvard University Seismographic Station.* J. B. Woodworth.

Lat., 42° 22′ 36″ N.; long., 71° 06′ 59″ W. Elevation, 5.4 meters. Foundation: Glacial sand over clay.

Instruments: Two Bosch-Omori 100 kg. horizontal pendulums (mechanical registration).

Instrumental constants.. {E 80 23 0; N 50 25 4:1} (V, T_0, ε)

Date.	Character.	Phase.	Time.	Period, T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Dec. 30	.....	iM_E	3 07 08	.....	*500	.....	.....	Local frost cracks; ground half bare, half iced over temperatures from 0° to −14°F on a.m. of 30th, Greenwich mean time.
		C	3 07 10	.....	.....	.....	.....	
		F	3 07 13	.....	.....	.....	.....	
30	.....	iM_E	3 20 42	.....	*500	.....	.....	
		C	3 30 44	.....	.....	.....	.....	
		F	3 20 50	.....	.....	.....	.....	
30	.....	iM_E	3 21 48	.....	.....	.....	.....	
		F	3 21 56	.....	.....	.....	.....	
30	.....	iM_E	3 22 50	.....	.....	.....	.....	
		C	3 22 52	.....	*1,000	.....	.....	
		F	3 23 00	.....	.....	.....	.....	
30	.....	iM_E	4 09 42	.....	*1,300	.....	.....	
		F	4 09 47	.....	.....	.....	.....	
30	.....	iM_E	5 21 57	.....	*500	.....	.....	
		C	5 21 59	.....	.....	.....	.....	
		F	5 22 07	.....	.....	.....	.....	
30	.....	P_E	6 49 50	.....	.....	.....	6?	No reports.
		iM	6 49 50	.....	.....	.....	.....	
		C	6 49 51	.....	.....	.....	.....	
		F	6 49 56	.....	.....	.....	.....	
30	.....	M_E	7 03 20	.....	.....	.....	.....	
		C	7 03 22	.....	.....	.....	.....	
		F	7 03 29	.....	.....	.....	.....	
30	.....	iM_E	7 48 44	.....	.....	.....	.....	
		C	7 48 45	.....	.....	.....	.....	
		F	7 48 49	.....	.....	.....	.....	
30	.....	P_E	7 55 23	.....	.....	.....	10?	No reports.
		M	7 55 24	.....	.....	.....	.....	
		F	7 55 33	.....	.....	.....	.....	
30	.....	M_E	9 11 20	.....	.....	.....	.....	
		C	9 11 23	.....	.....	.....	.....	
		F	9 11 29	.....	.....	.....	.....	
30	.....	M_E	9 54 32	.....	.....	.....	.....	
		C	9 54 34	.....	.....	.....	.....	
		F	9 54 36	.....	.....	.....	.....	
30	.....	M_E	9 58 14	.....	.....	.....	.....	
		C	9 58 16	.....	.....	.....	.....	
		F	9 58 20	.....	.....	.....	.....	
30	.....	M	10 44 52	.....	.....	.....	.....	
		C	10 44 54	.....	.....	.....	.....	
		F	10 44 57	.....	.....	.....	.....	
30	.....	M	10 45 41	.....	.....	.....	.....	
		F	10 45 43	.....	.....	.....	.....	
30	.....	M	12 08 14	.....	.....	.....	.....	
		F	12 08 16	.....	.....	.....	.....	
30	.....	M	14 22 11	.....	.....	.....	.....	
		F	14 22 12	.....	.....	.....	.....	
31	.....	iM_E	6 40 46	.....	*500	.....	.....	†
		C	6 40 48	.....	.....	.....	.....	
		F	6 40 59	.....	.....	.....	.....	
31	.....	iM	9 44 08	.....	*250	.....	.....	†
		C	9 44 10	.....	.....	.....	.....	
		F	9 44 14	.....	.....	.....	.....	
31	.....	iM	11 26 55	.....	.....	.....	.....	
		C	11 27 01	.....	.....	.....	.....	
		F	11 27 06	.....	.....	.....	.....	

*Trace amplitude.

†Dec. 31, press report from Maynard, Mass., states that at an early hour this morning (eastern standard time) earth tremors shook houses, broke dishes, and caused people to think there had been an explosion. Several wide cracks in the ground, extending in some places more than half a mile, have been found. A large pear tree on the premises of William H. Millington on Bent Avenue was split from the base to the topmost limb. Two large crevices have been found on the Millington property.—(Note from Boston Post, Jan. 1, 1918, through Harvard University.)

Missouri. *Saint Louis. St. Louis University.* Geophysical Observatory. J. B. Goesse, S. J.

Lat., 38° 38′ 15″ N.; long., 90° 13′ 58″ W. Elevation, 160.4 meters. Foundation: 12 feet of tough clay over limestone of Mississippi system, about 300 feet thick.

Instrument: Wiechert 80 kg. astatic, horizontal pendulum.

Instrumental constants.. 80 7 5:1 (V, T_0, ε)

Date.	Character.	Phase.	Time.	Period, T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Dec. 21	III...	iP	18 09 12	.....	.....	.....	2,011	
		iS_E	18 12 36	.....	.....	.....	.....	
		iS_N	18 12 42	.....	.....	.....	.....	
		L_E	18 13 12	.....	.....	.....	.....	
		L_N	18 13 12	18	.....	*3,000	.....	
		M_N	18 20 24	.....	.....	.....	.....	
		M_E	18 22 06	12	*3,000	.....	.....	
		F	19 00 ..	.....	.....	.....	.....	
28	III...	e_N?	19 37 30	.....	.....	.....	.....	Shocks recorded intermittently on E–W.
		F_N	20 10 ..	.....	.....	.....	.....	
29	II....	iP	22 55 48	.....	.....	.....	2,736	
		iS_N	23 00 09	.....	.....	.....	.....	
		iS_E	23 00 12	.....	.....	.....	.....	
		L_N	23 01 18	30	.....	*12,000	.....	
		L_E	23	.....	.....	.....	.....	
		F	24 00 ..	.....	.....	.....	.....	

* Trace amplitude.

New York. *Buffalo. Canisius College.* John A. Curtin, S. J.

Lat., 42° 53′ 02″ N.; long., 78° 52′ 40″ W. Elevation, 190.5 meters.

Instrument: Wiechert 80 kg. horizontal.

Instrumental constants.. 80 7 5:1 (V, T_0, ε)

(Report for December, 1917, not received.)

New York. *Fordham. Fordham University.* Daniel H. Sullivan, S. J.

Lat., 40° 51′ 47″ N.; long., 73° 53′ 08″ W. Elevation, 23.9 meters.

Instrument: Wiechert, 80 kg.

Instrumental constants. {E 72 6.6 1.5:1; N 72 7.1 3.8:1} (V, T_0, ε)

Date.	Character.	Phase.	Time.	Period, T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Dec. 21	.....	eP_E	17 59 08	.....	.....	.....	.....	N–S not recording.
		eS_E	18 06 19	.....	.....	.....	.....	
		L_E	18 16 49	.....	.....	.....	.....	
		M_E	18 21 24	17	*2,060	.....	.....	
		C_E	18 33 24	.....	.....	.....	.....	
		F_E	19 05 24	.....	.....	.....	.....	
21	.....	eL?	21 16 44	12	.....	.....	.....	
		F	21 30 ..	.....	.....	.....	.....	
28	.....	eP_E	21 26 27	.....	.....	.....	.....	
		eP_N	21 26 29	.....	.....	.....	.....	
		eL	21 35 50?	.....	.....	.....	.....	
		M	{21 40 00; 21 57 00}	13	.....	.....	.....	Sinusoidal. No decided max.
		F	22 20 00	.....	.....	.....	.....	
29	.....	iP_E	22 52 32	.....	.....	.....	.....	N–S not recording satisfactorily.
		iS_E	22 57 45	.....	.....	.....	.....	
		L_E	23 02 04	.....	.....	.....	.....	
		M_E	23 07 04	14	*2,300	.....	.....	
		F_E	23 55 ..	.....	.....	.....	.....	

* Trace amplitude.

TABLE 2.—*Instrumental reports, December, 1917*—Continued.

Date.	Character.	Phase.	Time.	Period, T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.

New York. *Ithaca. Cornell University.* Heinrich Ries.

Lat., 42° 26′ 58″ N.; long., 76° 29′ 09″ W. Elevation, 242.6 meters.

Instruments: Two Bosch-Omori, 25 kg., horizontal pendulums (mechanical registration).

Instrumental constants..		V	T_0	ε
	E	13	22	4:1
	N	14	25	4:1

1917.			H. m. s.	Sec.	μ	μ	km.	
Dec. 21		e_N	18 03 17	4				
		S_N	18 10 26	7				
		L_N	18 18 25	24				
		M_N	18 30 18	11		*1,500		
		F	20 06 ..					
21		e_N	21 08 05	6				
		L_N	21 17 50	16				
		F	21 56 ..					
23		eL	16 10 50	13				
		F	16 24 ..					
26		e	14 04 07	9				
		F	14 13 ..					
28		e_N	21 30 21	8				
		eL_N	21 40 11	18				
		F	23 03 00					
29		P_N	22 56 56	6				
		S_N	23 02 18	13				
		L_N	23 06 19	43				
		M_N	23 13 25	20		*2,500		
		F	24 43 ..					

* Trace amplitude.

Panama Canal Zone. *Balboa Heights.* The Panama Canal.

Lat., 8° 57′ 39″ N; long., 79° 33′ 29″ W. Elevation, 27.6 meters.

Instruments: Two Bosch-Omori, 100 kg.

Instrumental constants..	V	T_0
	35	20

1917.			H. m. s.	Sec.	μ	μ	km.	
Dec. 26		M_E	1 25 48	20	*300			
		M_N	1 25 52	20		*500		
29		P	22 54 40					
		L_E	22 58 12					
		L_N	22 58 14					
		M_E	22 55 ..	20	*5,600		1,175	Direction probably NW.
		M_N	22 55 01	20		*1,500		
		F_E	23 48 40					
		F_N	23 49 ..					

* Trace amplitude.

Porto Rico. *Vieques. Magnetic Observatory.* U. S. Coast and Geodetic Survey. F. L. Adams.

Lat., 18° 09′ N; long., 65° 27′ W. Elevation, 19.8 meters.

Instruments: Two Bosch-Omori.

Instrumental constants..		V	T_0
	E	10	17.5
	N	10	18.0

1917.			H. m. s.	Sec.	μ	μ	km.	
Dec. 21		eL_E	18 24 55	24				North component not recording.
		M_E	18 36 ..	19	40			
		C	18 48 ..					
		F	19 05 ..					
29		e_E	22 57 05					
		e_N	22 57 20					
		eL_N	23 02 ..					North component not recording properly.
		eL_E	23 02 07	30				
		M_E	23 14 40	17	30			
		C	23 17 ..	12				
		F	23 56 ..					

Date.	Character.	Phase.	Time.	Period, T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.

Vermont. *Northfield. U. S. Weather Bureau.* Wm. A. Shaw.

Lat., 44° 10′ N ; long., 72° 41′ W. Elevation, 256 meters.

Instruments: Two Bosch-Omori, mechanical registration.

Instrumental constants..		V	T_0
	E	10	15
	N	10	16

1917.			H. m. s.	Sec.	μ	μ	km.	
Dec. 21		P	18 03 26					
		S	18 10 36					
		L	18 14 20					
		L	18 20 00	20				
		F	19 00 ..					
21		eL	21 20 30					
		F	21 45 ..					
28		P?	21 23 26					
		S?	21 30 00					
		eL	21 36 00					
		L	21 41 30	20				
		F	22 30 ..					
29		P	22 57 16					
		S	23 02 40					
		L	23 08 50	28				
		F	24 00 ..					

Canada. *Ottawa. Dominion Astronomical Observatory.* Earthquake Station. Otto Klotz.

Lat., 45° 23′ 38″ N.; long., 75° 42′ 57″ W. Elevation, 83 meters.

Instruments: Two Bosch photographic horizontal pendulums, one Spindler & Hoyer 80 kg. vertical seismograph

Instrumental constants..	V	T_0
	120	26

1917.			H. m. s.	Sec.	μ	μ	km.	
Dec. 21		O	17 54 45				5,040	
		P	18 03 16					
		S	18 10 ..					
		SR1	18 13 ..					
		L_N	18 17 ..	24				
		M_N	18 22 ..	20		200		
		L	18 25 ..	12				
		L	18 41 ..	12				
		L	18 46 ..	10				
		L	19 10 ..	10				
		LR1?	20 25 ..	irreg.				
		F	21 00 ..					
21		e_E	21 07 44					Probably of the order of about 5,000 kilometers, and resembles the preceding quake but is less intense.
			21 13 ..	4				
		e_N	21 13 30†	8				
		eL?	21 17 ..	16				
		L	21 18 ..	16				
			21 25 ..	12				
		L	21 33 ..	12				
		L_N	21 40 ..	10				
		F	22 10 ..					
23		eL_E	14 37 ..	12				
			14 45 ..					
		L_N	14 50 ..	8				
			14 55 ..					
		F	15 00 ..					
23		eS_N?	16 05 ..	5				
		eL_N	16 07 30†	15				
		L_N	16 17 ..	11				
		F	16 35 ..					
26		eL_N	13 57 ..	15				
			14 15 ..	11				
28		O	21 14 37				5,140	
		P_E	21 23 14					
		S	21 30 04					Note the marked resemblance in these phases to those on Dec. 21.
		SR1	21 33 02					
		eL_N?	21 36 30†					
		L	21 38 ..	18				
		M_N	21 42 30†	20		80		
		L	21 48 ..	12				
		L	21 53 ..	11				
		L	22 01 ..	9				
		L	22 10 ..	9				
		L_N	22 29 ..	11				
		F	23 00 ..					

† Original time in tenths of a minute.

TABLE 2.—*Instrumental reports, December, 1917*—Continued.

Canada. *Ottawa. Dominion Astronomical Observatory.* Earthquake Station. Otto Klotz—Continued.

Date.	Character.	Phase.	Time.	Period, T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Dec. 29	.....	*O*	22 50 29	.....	.....	.....	3,690	Guatemala.
		P	22 57 24	.....	.....	.....	.....	
		S	23 02 53	.....	.....	.....	.....	
		eL_E	23 06 30†	.....	.....	.....	.....	
		L	23 10 ..	30	.....	.....	.....	
		M	(22 16 ..	.....	.....	.....	.....	
			(23 24 ..	18	.....	.....	.....	
		I	23 30 ..	16	.....	.....	.....	
			(23 42 ..	12	.....	.....	.....	
			(24 00 ..	.....	.....	.....	.....	
30	.....	.....	00 10 ..	.....	.....	.....	.....	
		F	00 30 ..	.....	.....	.....	.....	

† Original time in tenths of a minute.

Canada. *Toronto. Dominion Meteorological Service.*

Lat., 43° 40′ 01″ ng., 79° 23′ 54″ W. Elevation, 113.7 meters. Subsoil: Sand and clay.

Instrument: Milne horizontal pendulum, North. In the meridian.

T_0
Instrumental constant.. 18. Pillar deviation, 1 mm. swing of boom=0.50″.

Date.	Character.	Phase.	Time.	Period, T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Dec. 20	.....	L_E	2 56 00	.....	.....	.....	.....	
		M	2 57 36	.....	*300	.....	.....	Gradual thickening.
		F	3 28 24	.....	.....	.....	.....	
21	.....	P	.....	.....	.....	.....	.....	P lost changing sheet.
		S or L.	18 10 18	.....	.....	.....	.....	
		Li....	18 18 36	.....	.....	.....	.....	
		Li....	18 21 36	.....	.....	.....	.....	
		M	18 24 12	.....	*6000	.....	.....	
		F?	20 05 30	.....	.....	.....	.....	
21	.....	L?	21 09 00	.....	.....	.....	.....	
		L	21 16 36	.....	.....	.....	.....	Air currents on.
		L_E	21 20 36	.....	.....	.....	.....	P and S masked.
		M	21 22 30	.....	*800	.....	.....	
		F	.....	.....	.....	.....	.....	
23	.....	L	14 38 48	.....	*50	.....	.....	
		F	14 42 54	.....	.....	.....	.....	
		L	16 06 36	.....	*50	.....	.....	
		F	16 09 54	.....	.....	.....	.....	
26	.....	L_E	4 46 42	.....	.....	.....	.....	
		Li....	4 47 12	.....	.....	.....	.....	
		M	4 48 00	.....	*500	.....	.....	Guatemala earthquake.
		F	5 19 30	.....	.....	.....	.....	
26	.....	Le	5 37 06	.....	.....	.....	.....	
		L	5 38 06	.....	.....	.....	.....	
		M	5 38 30	.....	*700	.....	.....	Guatemala.
		F	5 55 06	.....	.....	.....	.....	
26	.....	L_E	6 36 30	.....	.....	.....	.....	
		M	6 36 48	.....	*300	.....	.....	Guatemala.
		F	6 48 12	.....	.....	.....	.....	
26	.....	S or L.	13 55 42	.....	.....	.....	.....	
		L	13 59 24	.....	.....	.....	.....	
		M	13 59 48	.....	*200	.....	.....	Guatemala.
		F	14 17 42	.....	.....	.....	.....	
28	.....	S_E	21 30 06	.....	.....	.....	.....	No P waves registered.
		L_E	21 38 00	.....	.....	.....	.....	
		L	21 41 06	.....	.....	.....	.....	
		M	21 44 30	.....	*2300	.....	.....	
		L_E	22 04 24	.....	.....	.....	.....	
		F	23 43 42	.....	.....	.....	.....	
29	.....	L	20 27 54	.....	.....	.....	.....	
		L_E	20 29 48	.....	.....	.....	.....	
		M	20 30 06	.....	*300	.....	.....	Thickening.
		F	20 49 24	.....	.....	.....	.....	
29	.....	P	22 57 00	.....	.....	.....	.....	
		S	23 02 36	.....	.....	.....	.....	
		Li....	23 04 24	12?	.....	.....	.....	
		L	23 07 12	.....	.....	.....	.....	
		Li....	23 09 48	.....	.....	.....	.....	
		M	23 15 54	.....	*4100	.....	3,810	Disastrous Guatemala earthquake.
30	.....	L_E	1 01 06	.....	.....	.....	.....	
		F	2 03 36	.....	.....	.....	.....	
31	.....	L	16 31 06	.....	.....	.....	.....	
		L	16 35 30	.....	.....	.....	.....	
		M	16 41 24	.....	*200	.....	.....	Thickening.
		F	16 55 48	.....	.....	.....	.....	

* Trace amplitude.

Canada. *Victoria, B. C. Dominion Meteorological Service.*

Lat., 48° 24′ N.; long., 123° 19′ W. Elevation, 67.7 meters. Subsoil: Rock.

Instrument: Wiechert, vertical; Milne horizontal pendulum, North. In the meridian.

T_0
Instrumental constant.. 18. Pillar deviation, 1 mm., swing of boom=0.54″.

Date.	Character.	Phase.	Time.	Period, T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Dec. 20	.....	M	2 50 00	.....	*100	.....	.....	
21	.....	P	17 58 21	.....	.....	.....	.....	
		L	18 02 39	.....	.....	.....	.....	
		M	18 06 07	.....	*7000	.....	2,660	Alaska*
		F	19 47 46	.....	.....	.....	.....	
			VERTICAL.		A_E			
		P	*17 59 08*	*3–4*	.....	.....	.....	
		S	*18 02 56*	*7–8*	.....	.....	.....	
		L	*18 03 45*	*12–14*	.....	.....	.....	
		M	*18 07 58*	*12*	*67*	.....	*2,390*	
21	.....	P	20 51 18	.....	.....	.....	.....	
		S	20 55 14	.....	.....	.....	.....	
		L	21 00 10	.....	.....	.....	.....	
		M	21 05 05	.....	*300	.....	2,390	Alaska.
		F	21 39 30	.....	.....	.....	.....	
22	.....	P or L.	14 20 33	.....	.....	.....	.....	
		M	14 22 32	.....	*200	.....	.....	
		F	14 31 37	.....	.....	.....	.....	
23	.....	L	14 20 37	.....	.....	.....	.....	
		M	14 22 01	.....	*200	.....	.....	
		F	14 32 43	.....	.....	.....	.....	
23	.....	P or L.	15 48 54	.....	.....	.....	.....	
		M	15 50 52	.....	*200	.....	.....	
		F	15 58 14	.....	.....	.....	.....	
26	.....	P?	4 54 26	.....	.....	.....	.....	
		L	4 58 52	.....	.....	.....	.....	
		M	5 01 20	.....	*200	.....	?	Guatemala.
		F	5 03 18	.....	.....	.....	.....	
26	.....	P	5 42 55	.....	.....	.....	.....	
		S?	5 45 58	.....	.....	.....	.....	
		L	5 48 57	.....	.....	.....	.....	
		M	5 51 55	.....	*300	.....	.....	Guatemala.
		F	5 56 53	.....	.....	.....	.....	
26	.....	M	6 49 27	.....	*100	.....	.....	Guatemala.
26	.....	P	13 36 04	.....	.....	.....	.....	
		S	13 40 02	.....	.....	.....	.....	
		L	13 42 01	.....	.....	.....	.....	
		M	13 44 30	.....	*300	.....	.....	Guatemala.
		F	13 51 26	.....	.....	.....	.....	
28	.....	P	21 19 20	.....	.....	.....	.....	Alaska, fine record.
		L	21 22 49	.....	.....	.....	.....	
		M	21 28 16	.....	*2,000	.....	2,070	
		L_E	21 58 54	.....	.....	.....	.....	
		F	22 50 35	.....	.....	.....	.....	
			VERTICAL.		A_E			
		P	*21 19 05*	.....	.....	.....	.....	
		S	*21 22 47*	.....	.....	.....	.....	
		L	*21 23 47*	.....	.....	.....	.....	
		M	*21 27 49*	.....	*67*	.....	*2,220*	
		F	*22 02 00?*	.....	.....	.....	.....	
29	.....	P	20 39 33	.....	.....	.....	.....	
		L	20 42 33	.....	.....	.....	.....	
		M	20 44 03	.....	*200	.....	.....	
		F	20 49 33	.....	.....	.....	.....	
29	.....	P	22 58 09	.....	.....	.....	.....	
		S	23 03 30	.....	.....	.....	.....	
		L	23 07 26	.....	.....	.....	.....	
		M	23 17 46	.....	*8,600	.....	.....	Guatemala.
		F	25 09 24	.....	.....	.....	.....	
			VERTICAL.		A_E			
		P	*22 58 19*	*8*	.....	.....	.....	
		S	*23 05 01*	*12*	.....	.....	.....	
		L	*23 11 31*	*18*	.....	.....	.....	
		M	*23 17 15*	*12*	*23*	.....	*4,990*	*Guatemala.*
		F	? ? ?	.....	.....	.....	.....	
31	.....	M	16 29 06	.....	*100	.....	.....	

* Trace amplitude.

TABLE 3.—*Late reports (instrumental).*

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
Alaska. *Sitka. Magnetic Observatory.* U. S. Coast and Geodetic Survey. J. W. Green.								
Lat. 57° 03′ 00″ N.; long., 135° 30′ 06″ W. Elevation, 15.2 meters.								
Instruments: Two Bosch-Omori, 10 and 12 kg.								
Instrumental constants...				V: E 10, N 10	T_0: E 16.7, N 15.4			
1917. Nov. 16		e_E	H. m. s. 3 31 34	Sec.		μ	km.	
		e_N	3 32 54					
		eL_N	3 50 30	32				
		M_N	4 02 56	32		20		
		F	5 38 ..					
Massachusetts. *Cambridge. Harvard University Seismographic Station.* J. B. Woodworth.								
Lat., 42° 22′ 36″ N.; long., 71° 06′ 59″ W. Elevation, 5.4 meters. Foundation: Glacial sand over clay.								
Instruments: Two Bosch-Omori 100 kg. horizontal pendulums (mechanical registration).								
Instrumental constants..				V: E 80, N 50	T_0: E 23, N 25	ε: E 0, N 4:1		
1917. Nov. 24		L_E	12 11 31	20				
		F	12 21 47					
Missouri. *Saint Louis. St. Louis University.* Geophysical Observatory. J. B. Goesse, S. J.								
Lat., 38° 38′ 15″ N.; long., 90° 13′ 58″ W. Elevation, 160.4 meters. Foundation: 12 feet of tough clay over limestone of Mississippi system, about 300 feet thick.								
Instrument: Wiechert 80 kg. astatic, horizontal pendulum.								
Instrumental constants..				V: 80	T_0: 7	ε: 5:1		
1917. Nov. 6	I.	S_N	14 02 12					These were omitted from the regular report for November, 1917.
		S_E	14 02 24					
		L	14 03 36				2,600	
		F_E	14 08 ..					
		F_N	14 10 ..					
7	I.	eP_N	1 41 54					
		S_N	1 44 18				2,400	
		S_E	1 44 30					
		L_E	1 45 18					
		L_N	1 45 30					
		F_E	1 52 00					
		F_N	1 52 06					

SEISMOLOGICAL DISPATCHES.[1]

Idaho Falls, Idaho, December 12, 1917.

Distinct vibrations of the earth were felt here at 4 o'clock this morning. No damage was done. (Assoc. Press.)

New York, N. Y., December 27, 1917.

Guatemala City was partly destroyed by an earthquake on Christmas Day according to meager advices reaching here tonight. According to the message, the disturbance began late Tuesday night and was still continuing at 1 o'clock Wednesday afternoon. (International News.)

San Salvador, December 30, 1917.

Guatemala City has been completely destroyed by an earthquake. (Assoc. Press.)

Cable to Navy Department, December 30, 1917.

Bad earthquake yesterday finished the work of others. Everything in ruins and beyond description as a result of last night's shock. One hundred and twenty-five thousand people are in the streets.

[1] Reported by the organization indicated and collected by the seismological station, at Georgetown University, Washington, D. C.

Guatemala City, Guatemala, December 31, 1917.

Earth shocks that began here at 11 o'clock Christmas night, and are still continuing, caused millions of dollars of damage to this city, the death of a few persons, and injury of about 100 others. Every house in the city was rendered uninhabitable, and the entire population is living in the parks and open spaces. The first shocks were light, giving warning of the heavy ones that might follow. The devastation wrought was widespread. (Assoc. Press.)

EARTHQUAKES FELT IN THE UNITED STATES DURING 1917.

W. J. HUMPHREYS,
Professor in Charge of Seismological Investigations.

[Dated: Weather Bureau, Washington, D. C., Feb. 2, 1918.]

During the year 1917, 112 separate earthquakes strong enough to be felt were reported from different parts of the continental United States, as listed in the accompanying Table 1 and graphically represented (a dot for each report) on Chart XI (XLV–122) at the end of this issue of the REVIEW.

None of the 'quakes reported resulted in any appreciable damage.

'Quakes of moderate intensities, *V–VI* (Rossi-Forel), occurred in California on March 3, April 13, on six dates in May, and on August 19 and 28; at Panhandle, in Texas, on March 28; in northeastern New York on May 22, and in the State of Washington on November 12 and 14.

A 'quake of intensity *VII* on July 7 broke the Los Angeles aqueduct.

On April 9 a 'quake of intensity *VI*, central in eastern Missouri, was felt in 10 States. A second shock of intensity *V* followed the first 2 hours and 43 minutes later, and was felt in both Missouri and Illinois. This quake is discussed in detail by R. H. Finch in this REVIEW, April, 1917, pages 187–188.

On September 3 a 'quake of intensity *VI* was reported from 34 separate points in Minnesota, central about Brainerd, Lincoln, and Staples. This 'quake is discussed in detail by C. J. Posey in this REVIEW, November, 1917, pages 556–558.

TABLE 1.—*Places in the United States reporting earthquakes during 1917.*

[Consult also Chart XI (XLV–122) in this issue.]

Place.	Approximate latitude (north).	Approximate longitude (west).	Number of quakes reported.	Place.	Approximate latitude (north).	Approximate longitude (west).	Number of quakes reported.
ALABAMA.	° ′	° ′		CALIFORNIA—con.	° ′	° ′	
Greensboro	32 41	87 32	1	Cedarville	41 32	120 08	2
Rosemary	32 40	87 30	1	Cloverdale	38 46	123 00	1
ARKANSAS.				Coachella	33 40	116 10	1
				El Cajon	32 48	116 58	1
Black Rock	36 08	91 04	1	Eureka	40 48	124 11	3
Corning	36 23	90 33	1	Fairmont	34 45	118 25	1
Hardy	36 19	91 22	1	Ferndale	40 35	124 16	1
Marked Tree	35 32	90 22	1	Fillmore	34 23	118 54	1
Osceola	35 43	89 54	1	Heber	32 45	115 31	1
Paragould	36 05	90 25	1	Hollister	36 50	121 20	1
Piggott	36 22	90 10	1	Indio	33 43	116 12	2
Pocahontas	36 15	90 55	1	Julian	33 05	116 39	5
St. Francis	36 25	90 06		Lakeport	39 04	122 56	1
CALIFORNIA.				Lone Pine	36 37	118 01	2
				Los Angeles	34 03	118 15	2
Banning	33 58	116 52	1	Los Gatos	37 12	121 58	3
Barrett Dam	32 40	116 44	2	Markleeville	38 48	119 46	1
Berkeley	37 52	122 16	3	Mayfield	37 23	122 05	1
Bishop	37 22	118 24	4	Mecca	33 34	116 05	2
Blythe	33 35	114 38	1	Mesa Grande	33 11	116 45	1
Boulevard	32 38	116 15	1	Mojave	35 03	118 12	1
Brawley	33 00	115 31	4	Mount Wilson	34 13	118 04	3
Cahuila	33 32	116 45	4	Neenach	34 47	118 37	1
Calexico	32 41	115 30	22	Nellie	33 22	116 52	1
Campbell	37 17	121 57	1	Nordhoff	34 35	119 14	1
Carmel	36 34	121 56	1	Ojai	34 25	119 12	3
				Olancha	36 15	118 00	1
				Owenyo	36 40	118 01	1

TABLE 1.—*Places in the United States reporting earthquakes during 1917*—Continued.

[Consult also Chart XI (XLV-122) in this issue.]

Place.	Approximate latitude (north).	Approximate longitude (west).	Number of quakes reported.
CALIFORNIA—con.	° ′	° ′	
Oxnard	34 12	119 08	1
Point Loma	32 43	117 15	1
Salinas	36 36	121 40	4
San Francisco	37 48	122 26	5
San Jose	37 20	121 54	3
San Luis Obispo	35 18	120 39	3
Santa Barbara	34 23	119 40	2
Santa Cruz	36 57	122 02	2
Santa Maria	34 58	120 28	3
Saugus	34 23	118 33	2
Soledad	36 38	121 16	1
Spreckles	36 35	121 38	1
Stanford University	37 27	122 09	2
Table Bluff	40 39	124 15	1
Towle	39 14	120 48	1
Ventura	34 17	119 17	2
Victorville	34 32	117 18	1
Warner Springs	33 17	116 39	1
Watsonville	36 55	121 46	2
Yorba Linda	33 51	117 50	3
IDAHO.*			
Ashton	44 04	111 29	1
Chesterfield	42 53	111 52	1
Cottonwood	46 03	116 20	1
Fort Hull	43 09	112 10	1
Idaho Falls	43 29	112 01	1
Irwin	43 25	111 20	1
Pierson	44 03	114 48	1
Pocatello	42 52	112 29	1
Sugar	43 52	111 44	1
ILLINOIS.			
Alton	38 54	90 12	1
Anna	37 27	89 17	2
Bloomington	40 29	89 01	1
Cairo	37 00	89 10	2
Carbondale	37 45	89 14	1
Carlinville	39 17	89 53	1
Carterville	37 46	89 05	1
Chester	37 55	89 50	1
Danville	40 09	87 36	1
Decatur	39 52	88 58	1
Edwardsville	38 48	89 59	1
Elizabethtown	37 27	88 12	1
Equality	37 44	88 22	1
Fairview	40 38	90 12	1
Golconda	37 22	88 31	1
Grafton	38 59	90 26	1
Greenville	38 53	89 25	1
Griggsville	39 42	90 43	1
Harrisburg	37 45	88 34	1
Highland	38 44	89 42	1
McLeansboro	38 07	88 34	1
Mascoutah	38 30	89 48	1
Morrisonville	39 31	89 30	1
Nashville	38 22	89 23	1
New Athens	38 18	89 52	1
New Burnside	37 34	88 45	1
Pulaski	37 15	89 11	1
Quincy	39 55	91 22	1
Shawneetown	37 42	88 10	1
Sparta	38 08	89 43	1
ILLINOIS—cont'd.	° ′	° ′	
Springfield	39 48	89 39	1
Staunton	39 01	89 50	2
Valmeyer	38 18	90 19	2
Vienna	37 25	88 54	1
Waterloo	38 19	90 11	3
White Hall	39 27	90 25	1
INDIANA.			
Evansville	37 58	87 33	1
Trevlac	37 16	86 21	1
IOWA.			
Cedar Rapids	41 56	91 39	1
Clinton	41 50	90 13	1
Davenport	41 30	90 38	1
Eldridge	41 38	90 35	1
Keokuk	40 22	91 26	1
Keasauqua	40 45	91 56	1
KANSAS.			
Lawrence	38 58	90 15	1
KENTUCKY.			
Bardwell	36 53	89 01	1
Hickman	36 35	89 11	1
Laketon	36 52	89 00	1
Milburn	36 49	88 53	1
Paducah	37 06	88 37	1
Smithland	37 09	88 29	1
Water Valley	36 35	88 50	1
Wickliffe	36 58	89 06	1
MINNESOTA.			
Aldrich	46 23	94 53	1
Alexandria	45 53	95 20	1
Brainerd	46 21	94 08	1
Crosby	46 30	93 51	1
Crow Wing	46 17	94 15	1
Eagle Bend	46 10	95 00	1
Fort Ripley	46 09	94 17	1
Henning	46 20	95 23	1
Grant	46 37	94 33	1
Gull Lake Dam	46 27	94 16	1
Jenkins	46 38	94 17	1
Leader	46 30	94 36	1
Lincoln	46 13	94 37	1
Long Prairie	45 58	94 50	1
McGregor	46 37	93 16	1
Merrifield	46 30	94 06	1
Milaca	45 44	93 38	1
Minneapolis	44 59	93 18	1
Motley	46 20	94 36	1
Onamia	46 04	93 38	1
Parkers Prairie	46 10	95 16	1
Philbrook	46 18	94 40	1
Pierz	45 58	94 02	1
Pillager	46 20	94 24	1
Pine River Dam	46 42	94 23	1
Pequot	46 37	94 16	1
Sauk Center	45 47	94 57	1
Staples	46 22	94 45	1
Sylvan	46 21	94 22	1
MINNESOTA—con.	° ′	° ′	
Verndale	46 24	94 59	1
Wadena	46 27	95 06	1
Red Lake	47 55	95 00	1
MISSISSIPPI.			
Evansville	34 38	90 19	1
MISSOURI.			
Allenton	38 30	90 40	1
Augusta	38 34	90 51	1
Bismarck	37 48	90 36	1
Bloomfield	36 54	89 53	1
Brule	37 45	90 48	1
Cape Girardeau	37 20	89 31	2
Columbia	38 57	92 20	1
Des Arc	37 18	90 37	1
De Soto	38 06	90 33	2
Doniphan	36 38	90 47	1
Dudley	36 48	90 04	1
Farmington	37 47	90 24	1
Fredericktown	37 43	90 16	1
Glencoe	38 32	90 36	1
Graniteville	37 38	90 44	1
Greenville	37 07	90 25	1
Hannibal	39 41	91 20	1
Hematite	38 13	90 30	2
Hendrickson	36 50	90 26	3
High Ridge	38 27	90 32	1
Hilderbrand			2
Hogan	37 32	90 39	1
Irondale	37 51	90 38	2
Ironton	37 36	90 37	2
Jackson	37 25	89 40	2
Kansas City	39 05	94 37	1
Kimmswick	38 23	90 22	1
Manchester	38 36	90 31	1
Marquand	37 27	90 07	1
New Madrid	36 35	89 32	2
Oak Ridge	37 34	89 48	2
Orchard Farm	38 51	90 27	1
Palmer	37 49	90 54	1
Perryville	37 45	89 51	2
Pevely	38 17	90 30	1
Poplar Bluff	36 46	90 21	1
Potosi	37 57	90 46	1
Rolla	37 57	91 45	1
Saco	37 22	90 25	1
St. Charles	38 48	90 30	1
St. Genevieve	37 58	90 02	2
St. Louis	38 38	90 12	1
St. Mary's	37 53	89 59	2
St. Peter's	38 48	90 40	1
Salem	37 40	91 30	1
Seventysix	37 45	89 38	2
Sikeston	36 54	89 34	1
Silvermine	37 34	90 27	2
Steelville	37 58	91 20	2
Sturdivant	37 03	90 00	1
Sulphur Springs	38 20	90 25	2
Uniontown	37 38	89 45	1
Van Buren	36 58	91 01	1
Warrenton	38 48	91 07	1
Wittenberg	37 45	89 32	1
Zion	37 26	90 17	2
MONTANA.	° ′	° ′	
Butte	46 00	112 31	1
NEVADA.			
Fallon	39 30	118 48	1
Rebel Creek	41 39	117 45	1
Winnemucca	40 58	117 43	2
NEW JERSEY.			
Atlantic City (Chelsea and Ventnor)	39 21	74 26	4(?)
Northfield	39 22	74 32	4(?)
Ocean City	39 18	74 34	1(?)
Pleasantville	39 23	74 32	1(?)
Somers Point	39 18	74 35	1(?)
NEW YORK.			
Alexandria Bay	44 22	75 54	2
Ausable	44 31	73 34	1
Canton	44 36	75 10	3
Gabriels	44 25	74 10	1
Glens Falls	43 21	73 36	1
Ogdensburg	44 42	75 30	1
SOUTH CAROLINA.			
Summerville	33 03	80 14	
TENNESSEE.			
Hornbeck	36 19	89 21	1
Jefferson City	36 08	83 30	2
Knoxville	35 56	83 58	1
Memphis	35 09	90 03	1
Newport	35 56	83 12	1
Springville	36 18	88 14	1
Talbott	36 08	83 24	2
Tiptonville	36 24	89 30	1
TEXAS.			
Panhandle	35 20	101 20	1
VERMONT.			
Ferrisburg	44 13	73 15	1
Montpelier	44 16	72 34	1
WASHINGTON.			
Ashford	46 48	121 56	1
Cedar Lake	47 24	121 43	1
Glenome	46 32	122 09	1
Longmire	46 45	121 50	3
Summit Inn	47 28	121 26	1
WISCONSIN.			
Madison	43 05	89 23	1
WYOMING.			
Bedford	42 54	110 58	1
Medicine Bow	41 52	106 08	1
Rawlins	41 47	107 15	1
Rock River	41 34	105 59	1

* Erase the red dot at Boise, Idaho, on Chart XI (XLV—122).

SECTION VI.—BIBLIOGRAPHY.

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C. FITZHUGH TALMAN, Professor in Charge of Library.

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C. FITZHUGH TALMAN, Professor in Charge of Library.

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SECTION VII.—WEATHER AND DATA FOR THE MONTH.

THE WEATHER OF DECEMBER, 1917.

P. C. DAY, Climatologist and Chief of Division.

[Dated: Climatological Division, Weather Bureau, Feb. 1, 1918.]

PRESSURE AND WINDS.

The distribution of the mean atmospheric pressure over the United States and Canada, and the prevailing direction of the winds for December, 1917, are graphically shown on Chart VII (XLV—118), while the means at the several stations, with the departures from the normal, are shown in Tables I and III.

During the first 15 days of December, 1917, high pressure persisted over the north-central districts, while in the Gulf and Atlantic coast regions pressure was more or less comparatively low. As a result, cold northerly or westerly winds prevailed to an unusual extent over the eastern and southern districts.

For a few days after the middle of the month, there was a reaction to lower pressure in northern districts, and a change to southerly winds brought some moderation in the cold. Near the beginning of the third decade, however, high pressure again advanced into the Northwest, and during the remainder of the month the anticyclonic conditions were unusually pronounced over the greater part of the region from the Rocky Mountains eastward. On the morning of the 27th sea-level pressure measured nearly 31 inches to the northward of Montana, and by the following morning this strong HIGH area had penetrated to the Dakotas and Minnesota. In the adjoining Canadian Provinces pressure was above 31.10 inches, the highest of the winter up to that date. This unusual pressure drifted southeastward, and cold northerly winds were experienced during the remainder of the month over most central and southern districts from the Rocky Mountains to the Atlantic and Gulf coasts.

For the month, as a whole, the pressure was unusually high over all central and northern districts from the Rocky Mountains eastward; in fact, save for a small area in the Rocky Mountains district from Wyoming to northern Idaho, the pressure averaged higher than the normal over all parts of the United States, and in Canada as far northward as observations were available. The pressure was particularly high in the Canadian districts, the averages exceeding the normal by from 0.20 to 0.30 inch. Over more southern districts and along the Pacific coast the departures were less pronounced.

The distribution of HIGHS and LOWS resulted in general northerly winds over the Atlantic and Gulf States, and over much of the Ohio Valley and from the upper Lakes Region westward to the Dakotas. Elsewhere variable winds prevailed.

TEMPERATURE.

At the beginning of the month the temperature was generally above the normal. During the next few days cold weather advanced into the Dakotas and gradually moved eastward and southward. The temperature of the first week of December averaged from normal to 7° above in the region west of the Rocky Mountains, the Central Plains, and the Cotton States, but in the central valleys and northeastern districts, and from the upper Lakes to Montana it was colder than usual. About the beginning of the second decade severe cold prevailed in the Lakes region, the Ohio Valley, and southward; killing frosts occurred at numerous points near the Gulf coast, and in northern Florida. Near the middle of the month colder weather overspread the Central Plains and districts to the east, particularly New England. The 10 days ending December 17 were warmer than normal in the far Southwest and in the central and northern districts west of the Rocky Mountains; but eastward the period was colder than normal. During the next few days there was a general change to warmer weather in central and northeastern districts and the week ending the 24th was warmer than normal in nearly all parts of the country, except the extreme Southwest, where it was cooler, and over the Middle and North Atlantic States, where it was normal.

At the beginning of the last week of the month a marked cold wave advanced southeastward from the Canadian Northwest, affecting practically all districts east of the Rocky Mountains. After a few days of slightly warmer weather, a second cold wave from the Northwest overspread the same area, being felt with special severity east of the Mississippi River, in southern Texas, and in Florida. At many points in New England and in eastern New York, the lowest temperature readings since the establishment of Weather Bureau stations were recorded. Meanwhile, west of the Rockies warm weather continued, and by the end of the month it was growing milder over most of the Plains region. The last week of the month averaged very cold east of the Rockies and warm to the westward.

For December as a whole, the region west of the Rocky Mountains was remarkably warm, while in Montana and the States eastward, and generally between the 100th Meridian and the Atlantic coast the month was decidedly cold. The temperature deficiency for the month averaged 12 degrees, or more, in parts of the Northwest and in the Ohio Valley; and in numerous Eastern States it was the coldest December of record On the other hand an excess temperature was nearly as marked west of the Rocky Mountains as the deficiency was to the eastward. In portions of Oregon and Idaho the excess was 12 degrees or more, and over large portions of the Plateau region and the North Pacific States the excess amounted to 5 to 10 degrees.

The contrast in temperature between the northern districts east of the Rocky Mountains and those immediately to the west was one of the marked features of the weather of this December. While many eastern sections experienced almost unprecedented cold, heavy snow, and disagreeable weather during practically the entire month, in the far West temperatures were abnormally high, and snowfall was unusually light. In southern Idaho and the eastern portions of Washington and Oregon, leaf buds were swelling at the close of the month, and in some localities fruit buds were ready to burst into bloom; the temperature during the last 20 days of the month did not fall as low as the freezing point.

PRECIPITATION.

During the early days of December generally fair weather prevailed, except light to moderate rain fell in portions of the Atlantic and North Pacific States. About the end of the first week moderate to heavy precipitation occurred in most eastern districts except the South Atlantic States; near the middle of the month considerable rain fell in the North Pacific States and snow from the Central Plains eastward, with heavy falls at many points in Pennsylvania and to the northward and eastward. During the next week rather heavy rain fell over the North Pacific States, but elsewhere little precipitation occurred. During the last week of the month moderate to light rain or snow fell in many sections, especially in the northern part of the country.

For the month as a whole the precipitation was light in most sections, and especially in southern districts, where, from the Plains States westward to the Pacific coast, large areas received no precipitation during the entire month, while the Great Plains, portions of the Mississippi Valley and of the Southeastern States received but small amounts.

In portions of the Ohio and lower Mississippi Valleys considerable precipitation occurred during the month, and along the Atlantic coast from the Carolinas northward there were moderate amounts, mostly in the form of snow. Snowfall was particularly heavy in the Ohio Valley, over portions of the Atlantic coast districts, and at points in the Lakes region.

In western Montana, and generally over Idaho, Washington, and Oregon, the precipitation was equal to, or above the normal; and occurred mostly as rain, save in the more northern portions and the higher mountains. A few sections of northern California had considerable rain or snow, but generally over that State the precipitation was markedly deficient, and the absence of any appreciable snow on the mountains at the close of the month was most unusual.

Snowfall.—Heavy snows occurred in portions of Pennsylvania, New York, and the New England States, and in general more snow fell east of the Rocky Mountains than is usual for December. In the far western mountains there was comparatively little snow; on the western slopes of the Rockies the amounts were generally light, and on the Sierra Nevada scarcely any snow fell, a condition probably unprecedented for December.

RELATIVE HUMIDITY.

The relative humidity for the month as a whole was above the normal in the Great Central Valleys, the northern Plains States, the far Northwest, the Lakes Region, New York, New England, and the Carolinas. Elsewhere there was relatively less moisture in the atmosphere than usually prevails in December, the deficiency being specially marked in the central and southern Plateau States.

GENERAL SUMMARY.

The unusually low temperature during most of the month in the districts to eastward of the Rocky Mountains allowed of little farm activity, and the heavy snow covering in portions of the Ohio Valley and eastern districts at times greatly hampered the transportation lines, and much inconvenience and actual suffering resulted from a lack of fuel and other necessary supplies.

In the southern districts severe cold caused more or less damage to winter oats and vegetables already above ground, and delayed the early planting of the usual outdoor truck crops.

In the far western districts the weather was unusually favorable for the first winter month. Outdoor work was possible during the greater part of the month, and winter vegetation made rapid growth. Pasturage of cattle was possible over considerable areas in the central and northern districts of this region, but in the southwest continued absence of moisture caused short and dry ranges, and much feeding was necessary.

A moderate covering of snow over the States east of the Mississippi during the greater part of the month afforded much needed protection to winter wheat, but there was little snow cover for this crop in the States between the Mississippi River and the Rocky Mountains, particularly over the more southern areas where wheat is grown.

In the far Northwest warm weather greatly favored the growth of wheat and the outlook for that crop was most promising.

Average accumulated departures for December, 1917.

Districts.	Temperature.			Precipitation.			Cloudiness.		Relative humidity.	
	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure from the normal.	General mean for the current month.	Departure from the normal.
	°F.	°F.	°F.	In.	In.	In.	0–10		P. ct.	
New England	21.5	−8.7	−25.7	2.64	−0.80	−3.90	3.8	−2.4	74	−2
Middle Atlantic	26.1	−9.1	−22.5	1.93	−1.00	−4.50	5.7	−0.1	67	−8
South Atlantic	38.6	−8.5	−10.9	1.85	−1.60	−12.40	5.4	+0.5	78	+1
Florida Peninsula	62.3	−3.6	−4.7	0.70	−1.30	−11.40	4.0	−0.6	78	−4
East Gulf	43.0	−6.1	−9.3	1.81	−2.70	−8.80	5.2	−0.3	75	−2
West Gulf	44.3	−4.8	−2.9	0.49	−2.40	−15.50	4.8	−0.4	74	0
Ohio Valley and Tennessee	26.4	−10.2	−29.6	1.50	−1.90	+0.30	6.5	+0.1	77	0
Lower Lakes	19.8	−9.1	−38.9	1.90	−1.00	−0.70	7.7	−0.1	80	+1
Upper Lakes	16.3	−8.2	−38.9	1.46	−0.60	−3.50	7.3	0.0	82	0
North Dakota	1.0	−10.8	−18.4	0.70	+0.10	−9.10	8.4	+2.8	86	+5
Upper Mississippi Valley	18.4	−8.9	−32.6	0.55	−1.10	−4.60	6.3	+0.3	81	+2
Missouri Valley	19.0	−7.9	−15.6	0.52	−0.50	−6.00	6.4	+1.1	80	+4
Northern slope	22.5	−1.5	−11.7	1.97	+1.10	−0.70	7.4	+2.1	74	+1
Middle slope	30.5	−2.4	−5.3	1.43	−0.60	−7.70	5.0	+0.8	68	0
Southern slope	42.3	−1.5	+7.2	0.02	−0.80	−8.90	2.5	−2.0	53	−15
Southern Plateau	50.4	+4.7	+3.7	T.	−0.60	−3.30	1.1	−2.1	40	−11
Middle Plateau	38.1	+6.8	−14.6	0.17	−0.80	−3.50	4.8	−0.3	57	−15
Northern Plateau	41.4	+9.3	+1.5	2.50	+0.80	−1.50	8.4	+1.5	74	−6
North Pacific	46.6	+4.5	+1.3	12.29	+4.90	−6.10	9.0	+1.2	89	−2
Middle Pacific	52.0	+3.5	+4.2	0.88	−0.40	−9.80	4.4	−1.1	74	+5
South Pacific	57.5	+4.5	+14.1	0.09	−2.00	−6.30	2.9	−1.4	64	−4

WEATHER CONDITIONS OVER THE NORTH ATLANTIC OCEAN DURING DECEMBER, 1916.

The data presented are for December, 1916, and comparison and study of the same should be in connection with those appearing in the REVIEW for that month.

Chart IX (XLV–120) shows for December, 1916, the principal storm tracks, the pressure, temperature, and prevailing direction of the wind at 7 a. m., 75th meridian time (Greenwich mean noon). Notes on the locations and courses of the more severe storms of the month are included in the following general summary.

PRESSURE.

The distribution of the average monthly pressure over the North Atlantic for the month, as shown on Chart IX, was unusual in some respects. There was no trace of the North Atlantic or Azores HIGH, the pressure rising gradually from the north coast of Scotland toward the Cape Verde Islands. The continental HIGH with a crest of 30.12 inches, was central near the eastern coast of Florida, the isobar of 30.1 inches, extending as far as the 67th meridian. The Icelandic LOW, with a minimum barometric pressure of 29.49 inches, was well developed and surrounded the Orkney Islands. A second LOW (29.55 inches) was central near St. Johns, Newfoundland, where the normal pressure is about 29.85 inches. The average pressure for the month was considerably below the normal over the greater portion of the ocean and the gradients were comparatively slight.

The pressure changes from day to day showed the usual marked winter variations, especially in the higher latitudes.

The following table gives for a number of selected 5-degree squares the average pressure for each of the three decades of the month as well as the highest and lowest individual readings reported during the month within the respective squares:

Pressures over the North Atlantic during December, 1916, by 5-degree squares.

Position of 5-degree squares.		Decade means.			Extremes.			
					Highest.		Lowest.	
Latitude.	Longitude.	I.	II.	III.*	Pressure.	Date.	Pressure.	Date.
°	°	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Dec.*	*Inches.*	*Dec.*
60-65 N	20- 25 W	29.92	29.78	29.24	30.13	2	28.91	28
60-65 N	5- 10 E	29.84	29.42	29.46	30.10	2	29.18	13
55-60 N	35- 40 W	29.96	29.96	29.27	30.22	9	28.96	28,30
55-60 N	0- 5 E	29.86	29.32	29.44	30.15	2	28.92	13
50-55 N	55- 60 W	29.77	29.62	29.47	30.12	4	29.00	29
50-55 N	10- 15 W	29.89	29.37	29.57	30.30	4	28.87	20
45-50 N	65- 70 W	29.84	29.63	29.87	30.30	4	28.90	23
45-50 N	40- 45 W	30.11	29.70	29.25	30.41	1	28.56	27
40-45 N	70- 75 W	29.93	29.78	30.05	30.40	27	29.30	16
40-45 N	55- 60 W	29.73	29.55	29.63	30.32	4	29.00	20
40-45 N	30- 35 W	30.29	29.69	29.62	30.40	9	29.37	21
40-45 N	10- 15 W	29.96	29.46	29.96	30.48	31	29.30	18,20
35-40 N	0- 5 W	29.85	29.70	30.17	30.44	28	29.50	11
30-35 N	70- 75 W	30.09	29.94	30.20	30.32	27,31	29.63	16
30-35 N	55- 60 W	29.98	29.97	29.99	30.30	5	29.69	9,16
25-30 N	95-100 W	30.02	30.04	29.98	30.40	15	29.63	20
25-30 N	80- 85 W	30.12	30.08	30.12	30.28	31	29.90	18
25-30 N	45- 50 W	30.01	29.96	29.99	30.12	3,5	29.73	16
25-30 N	15- 20 W	29.85	29.90	30.15	30.31	27	29.59	16
20-25 N	30- 35 W	29.99	29.96	30.07	30.18	27	29.72	16

* Mean of last 11 days of month.

The mean and extreme pressures presented in the above table are based on the daily pressure values, determined by interpolation for each square, on the MS. daily synoptic charts of the North Atlantic compiled by the Marine Section of the Weather Bureau.

GALES.

The number of days on which gales were reported during the month varied greatly over the different divisions of the ocean. In the waters between the 35th and 45th parallels, and the 50th meridian and the American coast, the greatest number recorded in any 5-degree square was 14, or 45 per cent, and the least 10 or a percentage of 32. These figures show that gales were much more numerous than usual in these waters, as the normal percentage varies from 13 to 23. Outside the area defined these conditions were reversed, especially along the middle and eastern divisions of the steamer routes, where the number of days with winds of gale force was considerably less than usual.

On December 1 a LOW of 29.45 inches was central near latitude 42° N., longitude 61° W., and southerly gales of from 40 to 65 miles an hour prevailed over a limited area in the eastern quadrants. On the same day a HIGH with a crest of 30.45 inches was near latitude 45° N., longitude 40° W., while a second long and narrow area of low pressure of comparatively slight intensity extended from the 50th to the 63d parallels, its major axis being about 200 miles west of and parallel with the European coast. A number of vessels between the 40th and 45th parallels, and the 15th and 26th meridians, encountered westerly and northwesterly gales of from 40 to 55 miles an hour accompanying comparatively high barometric readings in some cases.

The first LOW moved rapidly northward, and on the 2d the center was near Cape Whittle, Quebec, where the barometer reading was 28.84 inches. The HIGH, with a crest of 30.38 inches, was now central near latitude 45° N., longitude 30° W., while the second LOW of the 1st was too far north to plot accurately, due to lack of observations; but its center was apparently in the vicinity of the Faroe Islands. A third depression of slight intensity occupied an extensive area between the north coast of Spain and the Canary Islands. Heavy winds prevailed over the greater part of the ocean between the 35th and 50th parallels, and one vessel near latitude 42°N., longitude 27°W., encountered a northeast gale of 75 miles an hour, while the barometer read 30.30 inches. At the same time the observatory at Ponta Delgada, Azore Islands, reported a northeast wind of 55 miles an hour. From December 3 to 5, inclusive, the weather conditions were comparatively featureless, with weak gradients and light to moderate winds, although a LOW of slight intensity existed from the 3d to the 7th in the vicinity of the Madeira and Canary Islands. On the 6th a LOW was central near Father Point, Quebec; fog covered the Gulf of the St. Lawrence, while moderate to strong northeasterly gales were encountered along the American coast between Hatteras and New York. This disturbance moved in a southeasterly direction, increasing in intensity, and on the 7th the center was near Halifax, where the barometer reading was 29.18 inches. Northwesterly gales prevailed over the area between the 35th and 42d parallels, the 60th meridian, and the American coast, while the winds over the remainder of the ocean were light to moderate.

During the next three days this LOW drifted slowly toward the southeast, decreasing in intensity, and on the 10th its center was near latitude 40°N., longitude 52°W. A few vessels reported moderate gales between the 55th and 70th meridians, on the 8th and 9th, while by the 10th the wind velocity had decreased over this area. On the 9th a LOW with a minimum reading of 29.06 inches covered the southern part of the Irish Channel. Northerly and northeasterly gales of from 40 to 65 miles were prevalent in the region between the 45th and 57th parallels, and the 10th and 25th meridians; and hail was reported by a number of vessels within these limits. On the 10th this LOW was central near Brest, France, having remained nearly stationary in intensity, and the general conditions of wind and weather had also changed but little. Between the 11th and the 14th there was, in the vicinity of the Canadian coast, an area

of low pressure that varied slightly in intensity as well as in extent from day to day. On the 12th there was a second LOW near Hatteras, and one vessel about 100 miles east of that point reported a southwesterly hurricane of over 90 miles an hour. On December 16th a LOW was central near Boston where the barometric reading was 28.52 inches. At the same time a HIGH, with a crest of 30.24 inches, covered the northern part of the Gulf of Mexico, while the waters adjacent to the American coast between Florida and Nova Scotia were swept by strong westerly and northwesterly gales which attained a maximum velocity of 75 miles an hour about 150 miles south of Halifax. A number of vessels off the eastern coast of Florida encountered northwesterly gales of 40 to 55 miles an hour.

On the 12th a second LOW surrounded the Azores Islands, the barometer at Ponta Delgada reading 29.44 inches. This reversal of normal conditions was responsible for the strong easterly and northeasterly winds in the vicinity of the steamer lanes, in place of the usual westerlies. During the next 24 hours the Canadian LOW moved toward the east and on the 17th its center was near latitude 45° N., longitude 56° W.; it had decreased in intensity and the storm area contracted somewhat in extent, although strong gales still prevailed along the coast between Hatteras and Delaware Bay as well as in the region between the 40th and 45th parallels and the 50th and 65th meridians, where hail and snow also occurred.

On Chart III "Tracks of centers of Low Areas" (XLIV—145) in the MONTHLY WEATHER REVIEW for December, 1916, is shown a LOW (*I* on our Chart IX) that first appears on the chart near Dallas, Tex., on the morning of the 17th. This disturbance moved in an easterly direction with a uniform rate of translation, and on the 19th the center was near latitude 40° N., longitude 66° W. The storm area was limited in extent, although two vessels between the Bermudas and the 75th meridian reported westerly winds of 55 miles and 75 miles an hour, respectively. Low *I* continued its eastward movement and on the 20th was central in the vicinity of latitude 48° N., longitude 55° W.; heavy gales accompanied by snow still raged over a limited area between the 55th meridian and the American coast, although they did not extend south of the 40th parallel. During the next two days the LOW continued in its easterly course, and on the 22d the center was near latitude 43° N., longitude 33° W. On the 21st two vessels between the 40th and 45th parallels and the 55th and 60th meridians encountered winds of storm force, while on the 22d no specially heavy winds were recorded in this region. Low *I* then curved sharply toward the south and on the 23d recurved toward the east, probably passing over the Azores, as on the 24th the center was in the vicinity of Ponta Delgada. From there it took a northeasterly direction and on the 25th was central near latitude 42°, longitude 20°. Between the 22d and 25th the highest wind velocities within this area ranged from 40 to 48 miles an hour, one vessel about 200 miles west of Madeira recording the latter force on the 24th.

On December 22 a LOW (*II* on Chart IX) was central near the mouth of Delaware Bay, winds of from 50 to 65 miles per hour being recorded by vessels near by. This disturbance moved in a northeasterly direction and on the 23d the center was a short distance east of Father Point, Quebec, where the barometer reading was 28.86 inches. On the same day a HIGH with a crest of 30.26 inches covered the American coast between northern Florida and the Virginia Capes. Violent westerly gales were encountered by vessels midway between these two areas, the velocity of the wind ranging from 50 to 75 miles an hour. The LOW then moved some distance toward the east, and on the 24th was central about 200 miles north of St. Johns, N. F., the wind still blowing with undiminished force over the same territory as on the day before. The disturbance continued on its easterly course and on the 25th the center was near latitude 48°, longitude 42°; the wind had decreased considerably in force, although two vessels experienced moderate westerly gales accompanied by hail. Low *II* then curved sharply toward the northeast, increasing in intensity, and on the 26th it was near latitude 50°, longitude 38°, where the barometric reading had fallen to 28.70 inches. At the same time a HIGH with a crest of 30.60 inches covered the greater part of the Province of Quebec, while a second HIGH of 30.19 inches was central near Madeira. The abnormally steep gradients between these HIGHS and LOW *II* were responsible for the unusually large number of storms reported by vessels between the 25th meridian and the American coast. A maximum wind velocity of 65 miles an hour was reported by a vessel near latitude 40°, longitude 63°. During the next 24 hours *II* drifted slowly eastward while the two areas of high pressure remained nearly stationary. There was little change in the conditions of wind and weather during the following 24 hours, and on the 27th practically the entire ocean north of the 35th parallel was storm swept. The LOW then curved sharply northward, and on the 28th was in the vicinity of latitude 52°, longitude 33°. On the same date the Canadian HIGH of the 26th and 27th had moved rapidly toward the south and now surrounded Bermuda, where the barometric reading was 30.34 inches. The European HIGH had changed but little in position, although it had increased in extent, as the isobar of 30.3 inches extended from the coast of France to the Canary Islands. The storm area had contracted somewhat since the previous day, although moderate gales still prevailed over the greater part of the steamer lanes. On the 29th and 30th a LOW occupied an extensive territory immediately east of the Newfoundland coast; northwest gales with snow were recorded in the southwesterly quadrants, while east of the 40th meridian only moderate winds prevailed.

TEMPERATURE.

The mean monthly temperature of the air over the ocean was, as a whole, above the normal. In the northern part of the Gulf of Mexico, and in the waters adjacent to Canada and Newfoundland, the positive departures ranged from 5 to 8 degrees, while along the coasts of the United States and Europe they were somewhat less. Over a limited area between the Azores and the 50th parallel the temperature was either normal or slightly below, practically the same conditions holding true south of the 25th parallel.

The following table gives the departures at a number of Canadian and U. S. Weather Bureau Stations on the Atlantic and Gulf coasts.

	°F.		°F.
St. Johns, N. F.	+6.0	Norfolk, Va.	−0.3
Sydney, C. B. I.	+5.1	Hatteras, N. C.	−0.2
Halifax, N. S.	+3.7	Charleston, S. C.	+1.7
Eastport, Me.	+1.3	Key West, Fla.	+1.6
Portland, Me.	+0.2	Tampa, Fla.	+3.5
Boston, Mass.	+1.0	Mobile, Ala.	+2.4
Nantucket, Mass.	−2.2	New Orleans, La.	+3.0
Block Island, R. I.	−1.8	Galveston, Tex.	+1.4
New York, N. Y.	−0.6	Corpus Christi, Tex.	+3.3

The lowest temperatures reported by any vessel during the month was 26° F., which occurred on the 26th in the 5-degree square that includes the eastern coast of Newfoundland. The highest for the same square was 39° F., recorded on a number of different days.

FOG.

The number of days on which fog was reported in the higher latitudes was considerably less than usual. Off the Banks of Newfoundland, where the greatest amount ordinarily occurs, it was observed on only 3 days, a percentage of 10, while the normal percentage for this region is from 30 to 35. The steamer lanes were practically free from fog, as none was reported west of the 35th meridian and north of the 35th parallel, and it was observed on one day only between the 35th and 40th meridians. In the lower latitudes fog was much more prevalent than usual; over the waters adjacent to the American coast south of Hatteras it occurred on from 1 to 5 days, and in the vicinity of the Azores also was recorded on 2 days.

HAIL AND SNOW.

Hail was observed on 3 days off the Canadian and Irish coasts, while over the remainder of the steamer routes it was recorded on from 1 to 2 days.

Snow was reported on 4 days in the square between latitudes 40°–45° and longitudes 55°–60°, but it did not occur on more than one day in any 5-degree square in mid-ocean or along the American coast.

The European coast was entirely free of snow.

Winds of 50 mis./hr. (22.4 m./sec.), or over, during December, 1917.

Station.	Date.	Velocity.	Direction.	Station.	Date.	Velocity.	Direction.
		Mis./hr.				*Mis./hr.*	
Block Island, R. I.	1	52	nw.	North Head, Wash.	13	52	s.
Do	2	59	nw.	Do	15	84	s.
Do	8	59	e.	Do	16	78	s.
Do	9	54	w.	Do	17	64	s.
Do	13	60	e.	Do	18	66	s.
Do	14	76	e.	Do	21	58	s.
Do	28	54	nw.	Do	27	52	s.
Buffalo, N. Y.	8	74	w.	Do	28	52	s.
Do	9	78	w.	Do	29	50	se.
Do	10	62	w.	Do	31	58	s.
Do	28	50	sw.	Pensacola, Fla	8	57	s.
Canton, N. Y	9	56	sw.	Pittsburgh, Pa	8	51	sw.
Cheyenne, Wyo	5	54	w.	Pocatello, Idaho	12	50	sw.
Do	13	56	w.	Point Reyes Light,			
Do	17	53	w.	Cal	14	50	nw.
Do	18	53	w.	Do	25	70	s.
Do	20	62	w.	Do	26	57	se.
Cleveland, Ohio	8	66	w.	Portland, Me	14	60	se.
Columbus, Ohio	8	50	nw.	Providence, R. I.	2	58	nw.
Duluth, Minn	9	52	nw.	San Antonio, Tex.	7	51	nw.
Do	27	57	nw.	Sandusky, Ohio	8	50	w.
Eastport, Me	9	60	e.	Sandy Hook, N. J.	2	54	nw.
Do	14	70	e.	Do	8	57	e.
Erie, Pa	8	55	se.	Do	9	58	w.
Do	9	50	sw.	Do	10	53	w.
Hatteras, N. C	10	54	w.	Do	13	62	ne.
Do	29	50	n.	Do	14	65	w.
Do	30	58	n.	Sault Ste. Marie,			
Helena, Mont	17	56	sw.	Mich	27	52	nw.
Lexington, Ky	9	50	w.	Seattle, Wash	18	52	sw.
Mount Tamalpais,				Sioux City, Iowa	9	51	nw.
Cal	14	52	nw.	Tatoosh Island,			
Nantucket, Mass	8	70	se.	Wash	13	58	sw.
Do	14	76	sw.	Do	15	68	s.
New York, N. Y	2	68	nw.	Do	16	66	sw.
Do	8	50	w.	Do	17	52	sw.
Do	9	62	w.	Do	18	66	sw.
Do	10	58	w.	Do	21	56	e.
Norfolk, Va	9	50	w.	Do	23	56	e.
Do	10	55	nw.	Do	28	52	s.
North Head, Wash.	3	58	s.	Do	31	60	s.
Do	5	50	s.	Trenton, N. J.	14	52	nw.

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, December, 1917.

Section.	Temperature.								Precipitation.					
			Monthly extremes.								Greatest monthly.		Least monthly.	
	Section average.	Departure from the normal.	Station.	Highest.	Date.	Station.	Lowest.	Date.	Section average.	Departure from the normal.	Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	40.3	−6.1	Thomasville	79	4	2 stations	4	9†	1.73	−3.04	Healong Springs	3.30	Hamilton	0.40
Arizona	47.5	+5.0	Sentinel	87	31	Moccasin	1	8	0.00	−1.22	11 stations	T.	108 stations	0.00
Arkansas	34.8	−6.8	2 stations	81	3	2 stations	−21	9	1.29	−2.69	Corning	2.75	Subiaco	0.20
California	49.8	+3.1	El Cajon	92	29	Yreka	6	4†	1.43	−2.60	Helen Mine	11.04	45 stations	0.0
Colorado	30.7	+6.5	Hoeline	82	1	Dillon	−15	16	0.45	−0.66	Silver Lake	6.52	10 stations	0.0
Florida	54.9	−4.8	Davie	86	8†	Bristol	16	31	1.43	−1.50	Pensacola	3.73	Lakeland	T.
Georgia	39.8	−6.9	Brunswick	80	3	Ramhurst	0	30	1.63	−2.47	Brunswick	3.97	Albany	0.56
Hawaii (for November)	72.1	+0.4	Mahukona	96	12	Glenwood	49	20	6.37	−1.29	Papaikon	23.28	Waiawa	0 00
Idaho	36.9	+10.7	Magic	82	5	Bonanza	− 6	7	4.40	+1.09	Burke	18.95	Idaho Falls	0.17
Illinois	22.1	−8.1	Carbondale	70	2	2 stations	−23	15	0.90	−1.26	Cairo	2.31	Nashville	0.26
Indiana	22.0	−10.3	2 stations	68	2	Marengo	−30	10	1.38	−1.33	Vevay	3.70	2 stations	0.55
Iowa	14.5	−9.4	Keokuk	62	2	Washta	−40	29	0.56	−0.66	Lacona	1.70	Algona	0.14
Kansas	26.4	−5.9	Healy	82	1	Healy	−17	8	0.24	−0.63	Scott City	1.24	2 stations	0.00
Kentucky	26.5	−11.0	Paducah	72	2	Berea	−21	30	2.01	−1.78	Louisville (Cherokee Park).	1.58	2 stations	0.22
Louisiana	48.1	−3.6	Jennings	89	1	Liberty Hill	8	30	2.48	−2.14	Richland Plantation	6.15	Robeline	1.00
Maryland-Delaware	26.7	−7.2	Public Landing, Md.	59	8	Oakland, Md	−32	30	1.69	−1.90	Darlington, Md	3.32	Western Port, Md	0.57
Michigan	17.7	−7.8	Allegan	50	1	Humboldt	−38	30	1.40	−0.68	Deer Park	5.86	Eloise	0.16
Minnesota	5.2	−10.6	Tarbault	54	23	Itaska State Park	−47	29	0.57	−0.32	Red Lake Falls	2.32	Chatfield	0.13
Mississippi	41.5	−5.8	Hattiesburg	81	4	Hermando	− 3	9	2.12	−3.19	Laurel	4.18	Cleveland	0.52
Missouri	25.5	−8.7	Warsaw	82	2	Jackson (2)	−23	9	0.74	−1.40	Mount Vernon	2.51	Bethany	0.10
Montana	21.1	−1.3	Livingston	69	29	Browning	−41	12	2.73	+1.40	Trout Creek	14.26	Dell	0.10
Nebraska	20.9	−4.9	Lexington	72	1	Santee	−37	29	0.40	−0.33	Hartington	1.05	Antioch	0.04
Nevada	39.0	+7.7	Las Vegas	79	28	Clover Valley	− 7	6	0.14	−0.78	Marlette Lake	1.82	10 stations	0.00
New England	16.7	−8.7	Nantucket, Mass	54	8	Berlin, N. H	−44	30†	2.66	−0.64	Cavendish, Vt	4.57	Van Buren, Me	0.76
New Jersey	24.8	−8.2	Atlantic City	54	8	Culvers Lake	−29	31	3.18	−0.66	Jersey City	5.46	Trenton	1.55
New Mexico	39.1	+5.1	Socorro	81	31	4 stations	− 4	8	0.02	−0.72	Anchor Mine	0.49	115 stations	0.00
New York	16.7	−10.0	Beerston	52	21	Gabriels	−42	30	2.45	−0.71	Flushing	5.45	Avon	0.70
North Carolina	32.7	−8.9	2 stations	73	3	Banners Elk	−21	30	1.94	−2.16	Kinston	3.82	Highland	0.85
North Dakota	0.9	−12.1	New Salem	58	19	Willow City	−44	29	0.63	+0.09	Ashley	1.60	Buford	0.08
Ohio	21.4	−9.6	Peebles	60	21	Peebles	−31	11	1.31	−1.51	Wilmington	2.50	North Bass Island	0.58
Oklahoma	33.1	−6.3	Buffalo	84	1	Miami	−10	8†	0.17	−1.27	Bartlesville	1.70	Ravia	0.00
Oregon	42.8	+5.3	2 stations	72	28†	Crescent	− 4	3	6.72	+0.85	Government camp	37.90	Sunrise Valley	0.21
Pennsylvania	21.5	−9.4	Beaver Dam	52	25	Ebensburg	−28	30	1.78	−1.48	Mount Pocono	5.16	Ebensburg	0.60
Porto Rico	73.6	−0.9	2 stations	92	8†	3 stations	50	27†	4.81	−0.08	Rio Grande	16.39	Mayaguez	0.74
South Carolina	37.7	−8.4	Centenary	82	4	Lamdrum	− 6	30	1.47	−1.86	Conway	3.35	Bowman	0.34
South Dakota	12.2	−9.7	Hermosa	68	1	Eureka	−45	10	0.70	−0.04	Lead	2.16	Redfield	0.08
Tennessee	31.2	−8.7	2 stations	74	2	Mountain City	−32	30	1.81	−2.81	Union City	2.89	Arlington	0.65
Texas	46.0	−2.9	Flatonia	95	3	3 stations	0	8†	0.18	−2.31	Woodville	2.26	75 stations	0.00
Utah	36.4	+10.4	La Sal	76	12	Blacks Fork	−11	4	0.33	−0.73	Silver Lake	2.65	22 stations	0.00
Virginia	28.0	−9.3	Diamond Springs	64	25	2 stations	−27	30	1.75	−1.54	Blacksburg	3.17	Warsaw	0.85
Washington	38.7	+5.5	Kennewick	77	18	Snyder's Ranch	−14	24	11.55	+5.71	Cedar Lake	46.80	Hanford	0.50
West Virginia	24.3	−9.1	White Sulphur Springs.	67	3	Lewisburg	−37	30	1.51	−1.76	White Sulphur Springs.	3.32	Cuba	0.47
Wisconsin	12.1	−8.4	Stevens Point	50	24	Solon Springs	−38	29	0.56	−0.83	Plum Island	1.40	Baraboo	T.
Wyoming	26.2	+5.8	2 stations	71	22	Boyd	−26	9	1.05	+0.08	Kendall	8.03	Border	0.00

† Other dates also.

DESCRIPTION OF TABLES AND CHARTS.

(See the REVIEW for July, 1917, p. 388.)

TABLE I.—*Climatological data for Weather Bureau stations, December, 1917.*

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation.			Wind.				Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea-level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F		°F	°F.		°F	°F.		°F.	°F.	%	*In.*	*In.*		*Miles.*							*0–10*	*In.*	*In.*
New England.							21.5	−8.7											74	2.64	−0.8									3.8		
Eastport	76	67	85	30.06	30.14	+0.16	17.8	−7.5	47	9	25	−22	30	11	34	17	15	86	2.99	−1.0	9	11,044	nw.	70	e.	14	8	5	18	6.9	17.3	6.5
Greenville	1,070	6	....	28.94	30.18	.....	7.8	.....	33	25	16	−30	30	−1	36	....	....	....	3.62	.....	7	.....	.....	.....	.....	.....	19	3	9	....	36.2	20.0
Portland, Me	103	82	117	30.07	30.20	+ .17	17.8	−9.3	43	9	26	−21	30	10	34	16	9	68	4.22	+0.5	7	7,748	n.	60	se.	14	16	3	12	4.9	13.7	6.2
Concord	288	70	79	29.84	30.18	+ .12	15.7	−10.7	41	25	25	−17	30	6	37	....	....	....	2.32	−1.0	6	4,099	nw.	30	nw.	2	18	7	8	3.9	22.2	14.0
Burlington	404	11	48	29.74	30.22	+ .17	12.2	−10.3	41	25	21	−25	30	4	42	....	....	....	1.10	−0.6	6	9,491	s.	48	nw.	28	8	10	13	6.1	12.4	4.5
Northfield	876	12	60	.....	.....	.....	.....	.....	....	....	....	....	....	....	....	....	....	....	.....	.....	....	.....	.....	.....	.....	.....	....	....	....	....	.....	.....
Boston	125	115	188	30.04	30.18	+ .13	23.7	−7.9	48	9	32	−14	30	16	35	21	15	70	2.56	−0.8	12	9,148	nw.	48	e.	8	6	8	17	6.8	7.0	0.3
Nantucket	12	14	90	30.13	30.14	+ .09	29.4	−7.3	54	8	35	8	30	24	33	27	24	79	2.13	−1.5	14	14,104	nw.	76	sw.	14	4	7	20	7.6	6.8	T.
Block Island	26	11	46	30.13	30.16	+ .10	27.4	−9.2	52	8	34	−6	30	21	36	25	21	78	1.90	−1.9	8	17,668	nw.	76	e.	14	8	6	17	6.9	0.5	0.1
Narragansett Pier	....	9	....	.....	.....	.....	24.9	−7.6	52	9	33	−13	30	17	34	....	....	....	2.23	.....	8	.....	nw.	.....	.....	.....	16	6	9	....	2.0	0.9
Providence	160	215	251	30.00	30.18	+ .12	23.2	−8.4	48	9	31	−12	30	16	36	20	16	76	2.10	−1.8	9	11,487	nw.	58	nw.	2	11	9	11	5.2	5.7	0.3
Hartford	159	122	140	30.03	30.22	+ .15	20.9	−8.9	43	8	28	−18	30	13	29	17	11	69	3.22	−0.4	7	6,013	n.	32	sw.	9	14	6	11	4.6	13.7	5.7
New Haven	106	117	155	30.09	30.22	+ .15	23.4	−8.4	46	1	31	−12	31	16	31	19	13	69	3.90	+0.2	8	8,670	n.	43	nw.	14	15	3	13	4.9	10.8	3.3
Middle Atlantic States.							26.1	−9.1											67	1.93	−1.0									5.7		
Albany	97	102	115	30.14	30.25	+0.17	17.2	−10.3	42	21	25	−19	30	9	30	15	10	75	1.91	−0.7	6	6,205	nw.	29	s.	28	13	8	10	5.2	12.6	2.4
Binghamton	871	10	69	29.25	30.22	+ .13	18.3	−9.4	47	21	27	−22	30	10	34	....	....	....	1.69	−0.8	8	4,700	nw.	24	w.	9	7	8	16	6.6	18.0	2.0
New York	314	414	454	29.86	30.22	+ .13	25.0	−9.0	46	1	32	−13	30	18	29	21	14	64	3.70	+0.2	9	14,521	nw.	88	nw.	14	10	7	14	5.8	11.7	1.7
Harrisburg	374	94	104	29.85	30.28	+ .16	23.4	−9.4	45	1	29	−3	30	18	28	21	15	71	2.91	+0.3	9	5,607	n.	30	w.	10	7	7	17	6.5	17.1	3.6
Philadelphia	117	123	190	30.12	30.25	+ .14	28.0	−7.7	50	8	35	−4	30	21	30	24	18	67	2.53	−0.5	11	8,778	nw.	38	nw.	14	9	8	14	6.0	7.4	1.0
Reading	325	81	98	29.89	30.26	.....	23.4	.....	46	1	30	−6	30	17	26	21	17	75	2.24	−1.1	12	5,439	n.	40	e.	8	7	7	17	6.6	19.5	1.7
Scranton	805	111	119	29.34	30.25	+ .15	21.3	−8.5	43	21	28	−13	30	14	29	18	13	74	2.15	−0.5	10	6,205	sw.	35	w.	9	4	12	15	7.2	17.7	0.1
Atlantic City	52	37	48	30.17	30.23	+ .13	29.0	−7.4	54	8	36	−5	30	22	31	26	21	75	2.13	−1.6	7	7,305	n.	44	se.	8	9	9	13	5.6	3.7	0.0
Cape May	18	13	49	30.23	30.25	+ .14	29.3	−8.7	50	8	36	−2	30	23	24	....	....	....	2.43	−1.4	11	8,139	n.	48	s.	8	11	9	11	5.2	2.1	0.0
Sandy Hook	22	10	57	30.20	30.22	.....	26.5	.....	49	1	32	−5	30	21	26	24	20	75	4.00	.....	10	15,725	nw.	65	w.	14	10	8	13	5.5	3.8	T.
Trenton	190	159	183	30.01	30.23	.....	24.7	.....	47	1	32	−7	30	18	27	22	17	74	1.55	−1.6	9	10,276	n.	52	nw.	14	10	5	16	6.0	6.2	1.0
Baltimore	123	100	113	30.12	30.26	+ .13	28.4	−8.5	49	1	34	−2	30	22	29	25	17	65	1.96	−1.1	9	5,795	n.	32	sw.	8	8	9	14	6.1	8.3	0.5
Washington	112	62	85	30.13	30.26	+ .13	27.9	−8.2	50	21	34	−3	30	21	24	24	18	68	1.47	−1.7	7	5,406	n.	38	nw.	14	10	5	16	6.2	6.8	0.8
Lynchburg	681	153	188	29.48	30.26	+ .12	29.0	−9.3	62	21	38	−4	30	20	36	24	18	68	1.70	−1.6	8	4,186	n.	32	nw.	10	6	10	15	6.3	12.1	0.8
Norfolk	91	170	205	30.13	30.24	+ .11	33.8	−9.2	61	8	40	5	30	28	29	30	25	74	2.62	−0.9	13	11,253	n.	55	nw.	10	9	8	14	6.1	13.9	2.8
Richmond	144	11	52	30.10	30.27	+ .13	30.0	−11.0	59	21	38	−2	30	22	30	26	20	73	1.72	−1.3	8	6,535	nw.	36	e.	8	7	8	16	6.4	15.3	1.4
Wytheville	2,293	49	55	27.74	30.27	+ .12	24.2	−11.0	56	3	34	−7	30	14	37	21	19	84	2.22	−1.5	7	4,549	w.	42	w.	8	9	13	9	5.3	23.1	8.0
South Atlantic States.							38.6	−8.5											78	1.83	−1.6									5.4		
Asheville	2,255	70	84	27.78	30.27	+0.11	30.2	−7.6	63	3	41	−4	30	20	34	25	20	74	1.48	−2.6	8	6,167	nw.	33	n.	8	9	9	13	5.4	10.1	2.0
Charlotte	773	153	161	29.37	30.24	+ .08	33.4	−9.5	68	4	42	1	30	25	29	29	23	71	1.69	−2.2	8	7,976	ne.	46	sw.	8	12	11	8	4.8	6.8	0.3
Hatteras	11	12	50	30.15	30.16	+ .03	40.3	−8.5	64	8	45	17	30	35	22	37	36	90	3.07	−2.0	11	15,304	n.	58	n.	30	8	5	18	6.6	12.0	8.0
Manteo	12	4	46	.....	.....	.....	38.6	.....	60	1	46	12	31	32	....	....	....	....	2.62	−2.6	7	.....	ne.	.....	.....	.....	11	0	20	....	31.0	....
Raleigh	376	103	110	29.82	30.25	+ .10	32.6	−10.1	65	25	41	0	30	25	35	29	26	81	1.98	−1.2	11	5,889	ne.	39	sw.	8	7	7	17	6.3	9.7	1.4
Wilmington	78	81	91	30.12	30.22	+ .07	38.0	−9.2	73	3	46	6	31	30	31	33	29	78	2.45	−0.7	13	6,231	n.	44	sw.	8	13	5	13	5.3	4.2	3.5
Charleston	48	11	92	30.16	30.21	+ .06	42.0	−9.3	73	3	50	12	30	34	33	37	33	77	1.08	−2.1	10	9,033	n.	39	n.	29	15	5	11	4.7	1.0	0.5
Columbia, S. C	351	41	57	29.85	30.24	+ .08	37.9	−9.3	72	3	46	8	30	30	32	32	27	73	1.24	−1.7	11	5,806	ne.	39	sw.	8	12	7	12	5.4	2.1	1.0
Augusta	180	62	77	30.03	30.23	+ .07	39.6	−7.4	72	3	48	11	30	31	36	35	31	78	1.41	−2.0	8	4,576	ne.	29	sw.	8	16	2	13	4.9	0.9	0.6
Savannah	65	150	194	30.14	30.21	+ .06	43.8	−7.5	73	3	52	15	30	35	38	38	34	76	1.97	−1.1	8	8,574	ne.	42	nw.	8	12	6	13	5.5	0.1	T
Jacksonville	43	200	245	30.14	30.19	+ .05	48.4	−6.8	73	8	57	19	31	40	37	43	40	80	2.11	−0.9	7	10,010	n.	44	sw.	8	14	5	12	4.8	T.	0.0
Florida Peninsula.							62.3	−3.6											78	0.70	−1.3									4.0		
Key West	22	10	64	30.07	30.09	+0.01	66.4	−3.7	79	8	71	47	31	62	20	61	59	81	0.14	−1.7	4	7,407	ne.	36	n.	30	19	7	5	3.5	0.0	0.0
Miami	25	71	79	30.08	30.11	.....	63.6	−4.4	79	1	72	34	31	55	31	58	55	79	1.46	−0.8	10	6,039	nw.	27	nw.	30	16	6	9	4.3	0.0	0.0
Sand Key	23	39	72	30.05	30.08	.00	67.1	.....	76	8	70	49	31	64	20	62	59	77	0.11	.....	2	12,216	ne.	47	nw.	30	19	6	6	3.3	0.0	0.0
Tampa	35	79	92	30.12	30.16	+ .04	56.8	−2.7	76	8	66	27	31	47	30	50	46	76	0.49	−1.5	4	5,231	ne.	26	sw.	8	13	8	10	4.7	0.0	0.0
East Gulf States.							43.0	−6.1											73	1.81	−2.7									5.2		
Atlanta	1,174	190	216	28.95	30.22	+0.06	36.2	−8.4	68	2	44	8	9	28	27	32	26	70	0.89	−3.6	8	8,595	nw.	42	w.	8	17	2	12	4.5	4.9	0.0
Macon	370	78	87	29.83	30.24	+ .08	39.0	−7.8	72	2	48	13	30	30	36	34	29	72	1.31	−3.1	6	4,941	ne.	26	ne.	26	11	5	15	5.6	T.	0.0
Thomasville	273	49	58	29.89	30.20	+ .05	46.0	−6.5	74	3	56	20	31	36	37	40	35	74	1.82	−1.9	9	3,455	ne.	18	sw.	8	12	7	12	5.1	0.3	T.
Pensacola	56	149	185	30.14	30.20	+ .05	48.5	−5.4	69	2	57	19	30	40	36	44	39	76	3.73	−0.4	10	9,677	ne.	57	s.	8	11	5	15	5.6	T.	0.0
Anniston	741	9	57	29.42	30.24	+ .08	38.0	−6.2	70	2	48	8	30	28	34	....	....	....	1.01	−3.5	7	4,792	se.	30	w.	8	15	5	11	4.4	0.7	0.0
Birmingham	700	11	48	29.46	30.26	+ .10	39.2	−8.1	72	2	48	8	30	30	34	34	28	71	1.48	−3.1	8	5,236	n.	35	se.	7	14	5	12	5.0	0.4	0.0
Mobile	57	125	161	30.14	30.20	+ .05	48.2	−3.3	77	4	57	17	30	39	34	43	39	76	1.85	−2.7	11	7,528	n.	43	sw.	8	10	14	7	5.2	T.	0.0
Montgomery	223	100	112	29.98	30.24	+ .08	42.2	−6.9	73	2	51	15	9	33	32	37	32	72	1.86	−2.6	6	5,059	e.	29	se.	7	13	5	13	5.1	T.	0.0
Corinth	469	6	....	.....	.....	.....	34.3	.....	73	2	45	4	9	23	40	....	....	....	1.56	.....	9	.....	n.	.....	.....	.....	9	13	9	....	3.0	1.0
Jackson	304	5	....	.....	.....	.....	43.7	.....	79	2	54	10	30	33	39	....	....	....	2.41	.....	7	.....	ne.	.....	.....	.....	11	6	14	....	T.	0.0
Meridian	375	85	93	29.82	30.23	+ .07	41.8	−5.1	74	2	51	11	30	32	34	37	33	76	1.95	−3.3	7	4,696	ne.	31	w.	8	9	10	12	5.5	T.	0.0
Vicksburg	247	65	74	29.95	30.25	+ .10	42.6	−6.8	72	2	51	10	30	34	32	38	34	76	1.85	−3.2	7	5,142	ne.	36	nw.	8	10	6	15	6.2	T.	0.0
New Orleans	51	76	84	30.13	30.19	+ .06	51.4	−3.0	78	3	59	19	30	44	25	47	44	84	2.16	−2.3	8	5,861	ne.	32	sw.	7	12	7	12	5.3	0.0	0.0
West Gulf States.							44.3	−4.8											74	0.49	−2.4									4.8		
Shreveport	249	77	93	29.95	30.24	+0.11	43.2	−5.7	78	3	51	13	30	35	31	39	35	77	1.02	−3.4	2	5,411	ne.	38	nw.	7	11	7	13	5.7	0.0	0.0
Bentonville	1,303	11	44	28.80	30.22	+ .09	30.4	−7.1	71	2	40	−7	8	21	36	....	....	....	0.76	−2.0	4	4,968	ne.	25	nw.	9	12	10	9	5.2	6.8	0.0
Fort Smith	457	79	94	29.73	30.23	+ .10	35.0	−6.7	74	2	43	2	9	27	36	30	24	66	0.36	−2.5	1	6,248	e.	31	w.	9	11	8	12	5.2	2.1	0.0
Little Rock	357	139	147	29.86	30.26	+ .12	35.4	−8.1	70	2	43	5	9	28	33	31	26	71	1.24	−3.0	5	6,518	e.	33	nw.	9	12	4	15	5.6	6.6	0.0
Brownsville	57	4	26	.....	.....	.....	62.9	.....	87	5	74	24	30	52	39	....	....	....	0.32	.....	2	.....	n.	.....	.....	.....	....	....	....	....	....	....
Corpus Christi	20	69	77	30.15	30.17	+ .05	55.8	−0.8	87	7	63	24	30	49	39	51	48	79	T.	−1.3	0	7,959	n.	38	n.	7	6	11	14	6.4	0.0	0.0
Dallas	512	109	117	29.66	30.23	.....	41.2	.....	77	2	51	13	30	32	38	....	....	....	0.04	.....	4	6,472	n.	44	nw.	7	12	8	11	4.8	T.	0.0
Fort Worth	670	106	114	29.46	30.20	+ .08	41.6	−5.9	79	2	51	12	10	32	39	36	31	72	0.05	−1.2	3	7,614	nw.	49	nw.	7	14	7	10	4.6	0.0	0.0
Galveston	54	106	114	30.12	30.18	+ .06	52.8	−3.5	73	3	58	26	30	47	27	50	47	84	1.00	−2.7	8	8,778	n.	49	nw.	7	7	9	15	6.2	0.0	0.0
Houston	138	111	121	30.03	30.19	.....	52.0	−2.5	80	3	60	22	30	44	40	....	....	....	1.19	.....	7	5,700	n.	34	nw.	7	6	9	16	6.5	0.0	0.0
Palestine	510	64	72	29.65	30.20	+ .08	44.8	−4.6	80	3	53	18	30	37	49	40	38	82	0.45	−3.2	2	5,685	ne.	38	nw.	7	12	7	12	5.3	0.0	0.0
Fort Arthur	34	58	66	30.13	30.17	.....	50.2	.....	77	3	57	20	30	44	30	47	45	87	1.07	.....	9	7,360	ne.	39	nw.	7	9	11	11	5.3	0.0	0.0
San Antonio	701	119	132	29.43	30.17	+ .06	50.4	−2.7	81	7	60	19	30	41	46	44	36	65	T.	−1.6	0	5,862	ne.	51	nw.	7	14	9	8	4.6	0.0	0.0
Taylor	582	55	63	29.59	30.22	+ .11	45.6	−5.0	80	3	55	14	30	36	50	....	....	....	0.03	−2.6	2	7,314	n.	44	n.	7	10	12	9	5.1	0.0	0.0

TABLE I.—*Climatological data for Weather Bureau stations, December, 1917*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.												Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation.			Wind.						Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sealevel, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.						Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity.										
																									Miles per hour.	Direction.	Date.								
Ohio Valley and Tennessee.	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F. 26.4	°F. −10.2	°F		°F	°F		°F	°F		°F	°F			% 77	*In.* 1.50	*In.* −1.9		*Miles.*									*0–10* 6.5	*In.*	*In.*
Chattanooga	762	189	213	29.42	30.26	+0.10	34.3	−8.3	70	2	43	6	30	26	34	30	23	66	2.13	−2.2	9	5,850	ne.	42	s.	8	13	7	11	5.4	12.3	5.6
Knoxville	996	102	111	29.14	30.24	+ .08	32.6	−7.1	64	2	41	−2	30	24	37	29	24	75	1.38	−2.8	8	4,694	ne.	34	sw.	8	7	15	9	5.9	7.0	2.5
Memphis	399	76	97	29.84	30.29	+ .14	34.0	−9.5	70	2	42	2	9	26	31	30	25	74	1.33	−3.0	5	6,497	n.	38	sw.	9	14	4	13	5.2	11.2	1.5
Nashville	546	168	191	29.67	30.28	+ .13	31.4	−9.7	70	2	41	0	9	22	33	27	23	75	1.46	−2.4	10	6,681	ne.	42	w.	9	9	16	12	5.8	10.5	2.0
Lexington	989	193	230	29.15	30.28	+ .14	25.3	−11.1	60	2	33	−9	10	18	35				1.97	−1.4	11	10,488	sw.	50	w.	9	10	6	15	6.2	19.4	5.0
Louisville	525	219	255	29.69	30.30	+ .16	26.0	−12.1	60	2	34	−6	9	18	28	23	19	75	2.28	−1.4	11	9,154	n.	49	w.	9	7	5	19	6.8	24.6	2.3
Evansville	431	139	175	29.79	30.28	+ .15	26.6	−9.8	68	2	34	−5	9	19	31	24	21	81	2.12	−1.7	11	8,465	ne.	44	sw.	9	7	12	12	6.3	25.1	3.0
Indianapolis	822	194	230	29.34	30.27	+ .15	22.8	−9.8	56	24	30	−8	10	15	28	20	16	75	1.10	−1.9	12	8,871	s.	41	nw.	8	5	6	20	7.4	10.2	1.3
Terre Haute	575	96	129	29.62	30.27	.....	23.5	.....	56	24	31	−8	10	16	26	21	17	80	0.96	.....	11	7,326	nw.	34	nw.	9	3	12	16	7.4	11.0	1.0
Cincinnati	628	11	51	29.56	30.28	+ .15	22.3	−12.1	54	3	31	−13	11	14	35	20	17	82	1.56	−1.4	11	6,061	ne.	32	w.	8	6	9	16	6.6	16.3	1.9
Columbus	824	173	222	29.34	30.26	+ .14	21.3	−11.5	49	24	29	−9	11	14	33	19	15	73	1.31	−1.4	11	8,234	n.	30	nw.	8	6	10	15	6.7	14.5	2.8
Dayton	899	181	216	29.24	30.25	.....	21.8	−11.3	50	24	30	−8	11	14	34	20	17	82	1.15	−1.5	11	7,308	sw.	39	nw.	8	6	9	16	6.8	13.7	2.0
Pittsburgh	842	353	410	29.30	30.25	+ .14	24.5	−10.2	50	20	31	−5	10	18	29	22	17	75	1.19	−1.5	12	8,195	nw.	51	sw.	8	2	10	19	7.7	12.4	1.8
Elkins	1,940	41	50	28.09	30.28	+ .16	22.5	−10.0	52	3	33	−28	30	12	37	19	17	85	1.17	−2.2	16	2,678	w.	24	se.	8	5	8	18	7.3	9.0	3.4
Parkersburg	638	77	84	29.60	30.29	+ .15	24.8	−10.4	52	3	33	−10	30	17	34	22	19	83	0.90	−1.9	11	2,728	n.	29	sw.	8	9	7	15	6.5	8.6	1.0
Lower Lakes Region.							19.8	−9.1													89	1.90	−1.0									7.7		
Buffalo	767	247	280	29.34	30.21	+0.15	20.8	−9.3	44	21	27	−4	29	15	30	19	16	83	3.93	+0.6	18	13,639	w.	78	w.	9	1	11	19	7.4	37.1	2.9
Canton	448	10	61	29.71	30.22	.....	8.8	−14.1	43	21	18	−30	16	0	40	.....	.....	.....	1.76	−1.8	12	7,844	w.	56	sw.	9	14	5	12	5.1	19.2	3 1
Oswego	335	76	91	29.83	30.22	+ .16	18.1	−11.1	43	21	25	−21	30	11	28	16	14	84	1.02	−2.6	9	9,654	s.	47	w.	9	4	4	23	7.6	21.3	6.0
Rochester	523	97	113	29.63	30.23	+ .17	20.5	−8.4	45	24	27	−8	30	14	32	18	15	80	2.47	−0.4	17	6,741	w.	42	sw.	9	3	7	21	7.8	29.7	4.0
Syracuse	597	97	113	29.52	30.23	+ .16	17.8	−10.5	46	21	25	−20	30	11	34	16	14	86	4.03	+1.4	16	9,084	s.	48	sw.	9	3	10	18	7.3	36.0	3.0
Erie	714	130	166	29.41	30.21	+ .14	23.2	−8.5	48	21	29	−2	9	17	28	20	16	74	1.53	−1.5	14	12,124	se.	55	se.	8	2	5	24	8.2	14.2	2.0
Cleveland	762	190	201	29.38	30.24	+ .15	22.4	−8.7	49	24	28	−5	9	17	24	20	16	77	1.41	−1.2	15	10,208	s.	66	w.	8	3	7	21	8.0	13.5	2.0
Sandusky	623	62	105	29.53	30.25	+ .16	21.6	−9.5	50	24	28	−4	10	16	27	20	15	76	1.12	−1.2	8	9,542	sw.	50	w.	8	4	11	16	7.2	11.5	0.4
Toledo	628	208	243	29.54	30.26	+ .18	22.0	−8.5	50	24	29	−5	9	15	31	19	16	81	0.90	−1.4	9	9,947	nw.	46	sw.	9	8	11	12	6.0	9.8	0.1
Fort Wayne	856	113	124	29.30	30.27	.....	20.6	−6.7	50	24	28	−8	15	13	28	18	13	74	0.71	.....	10	6,516	sw.	31	nw.	8	8	10	13	5.9	7.1	0.2
Detroit	730	218	245	29.40	30.24	+ .17	21.8	−7.7	45	24	28	−4	9	16	30	20	17	82	0.88	−1.5	9	9,164	sw.	43	sw.	9	7	12	12	6.5	9.2	T.
Upper Lakes Region.							16.3	−8.2													82	1.46	−0.6									7.3		
Alpena	609	13	92	29.50	30.20	+0.18	17.0	−7.8	38	24	23	−8	30	11	27	16	14	86	0.79	−1.4	15	9,503	nw.	40	nw.	27	3	15	13	6.6	9.7	1.5
Escanaba	612	54	60	29.51	30.21	+ .18	14.6	−7.0	37	24	22	−14	28	7	37	13	11	88	1.00	−0.7	16	8,041	nw.	32	s.	17	9	5	17	6.5	11.3	4.0
Grand Haven	632	54	92	29.51	30.24	+ .19	20.8	−9.3	42	24	27	−9	15	15	25	19	15	76	1.13	−1.4	18	9,388	se.	44	w.	9	3	6	22	8.1	13.6	1.3
Grand Rapids	707	70	87	29.44	30.24	+ .19	21.1	−7.7	46	24	27	−7	15	15	28	19	15	79	0.82	−1.7	16	4,765	se.	27	nw.	27	2	8	21	7.8	9.7	1.0
Houghton	684	62	99	29.41	30.18	+ .16	12.5	−8.4	41	18	20	−13	28	5	36	.....	.....	.....	5.25	+2.8	23	7,964	e.	44	w.	24	1	4	26	9.0	52.7	23.4
Lansing	878	11	62	29.24	30.23	.....	19.1	−7.7	44	24	27	−13	15	11	31	17	14	85	0.74	−1.3	15	4,999	nw.	24	nw.	8	6	8	17	6.6	8.3	0.5
Ludington	637	60	66	29.48	30.21	.....	20.2	.....	40	24	26	0	9	15	26	19	17	86	1.98	.....	21	9,099	se.	42	nw.	9	0	6	25	8.7	32.9	6.8
Marquette	734	77	111	29.37	30.20	+ .18	14.6	−8.3	40	18	22	−12	28	8	36	12	10	84	3.86	+1.3	22	10,121	w.	47	s.	17	2	13	16	7.9	39.7	12.9
Port Huron	638	70	120	29.49	30.22	+ .16	19.4	−7.9	42	24	28	−2	9	13	30	18	15	85	0.96	−1.2	10	8,956	nw.	42	nw.	9	6	11	14	6.5	16.9	2.5
Saginaw	641	43	82	29.50	30.23	.....	19.1	.....	44	24	28	−7	14	12	29	17	15	86	0.90	−1.0	10	7,311	nw.	34	w.	8	4	4	23	7.9	8.3	0.3
Sault Ste. Marie	614	11	61	29.47	30.21	+ .21	11.2	−9.3	35	18	18	−20	29	4	29	10	7	80	1.72	−0.6	23	8,290	se.	52	nw.	27	5	6	20	7.8	18.6	10.6
Chicago	823	140	310	29.32	30.26	+ .18	22.4	−6.9	52	20	28	−3	10	16	28	20	15	74	0.88	−1.2	13	9,499	nw.	32	nw.	8	5	12	14	6.8	9.0	1.0
Green Bay	617	109	144	29.52	30.23	+ .19	15.2	−6.1	39	23	22	−14	29	8	37	14	8	73	0.38	−1.4	9	8,622	nw.	36	nw.	27	6	6	19	7.5	4.9	1.2
Milwaukee	681	119	133	29.46	30.24	+ .18	18.8	−7.2	45	24	25	−8	29	13	33	17	13	79	0.87	−1.0	10	8,665	nw.	36	se.	2	9	7	15	6.3	8.4	0.4
Duluth	1,133	11	47	28.95	30.25	+ .20	4.4	−13.3	36	19	14	−35	28	−5	45	3	1	91	1.07	−0.2	13	9,906	w.	57	nw.	27	12	7	12	5.7	11.3	6.0
North Dakota.							1.0	−10.8													86	0.70	+0.1									8.4		
Moorhead	940	8	57	29.23	30.33	+0.25	2.6	−8.1	45	19	11	−29	29	−6	29	1	− 2	81	0.55	−0.2	11	6,961	nw.	30	nw.	24	10	7	14	5.6	5.5	3.1
Bismarck	1,674	8	57	28.39	30.31	+ .23	3.2	−11.8	48	19	12	−37	29	−6	45	3	1	88	0.59	0.0	10	6,845	nw.	40	nw.	23	6	6	19	7.2	9.4	5.8
Devil's Lake	1,482	11	44	28.58	30.28	+ .22	−3.6	−11.6	42	17	6	−34	14	−13	33	− 4	− 6	88	0.66	+0.3	11	7,908	nw.	33	nw.	9	6	12	13	6.5	10.0	5.0
Ellendale	1,457	10	56	28.62	30.28	.....	3.6	.....	51	19	13	−37	29	−6	37	2	1	94	0.91	.....	12	10,526	nw.	49	n.	23	3	11	17	7.5	9.1	4.8
Grand Forks	835	12	89	.....	.....	.....	−1.0	.....	38	19	8	−35	29	−10	33	.....	.....	.....	1.27	.....	8	.....	se.	35	nw.	8	5	9	17	....	12.9	6.0
Williston	1,872	41	48	28.13	30.24	+ .18	2.0	−11.6	44	17	11	−29	12	−7	40	1	0	89	1.00	+0.3	16	5,410	n.	40	nw.	8	4	5	22	7.7	8.7	5.5
Upper Mississippi Valley.							15.4	−8.9													81	0.55	−1.1									6.3		
Minneapolis	918	10	208	29.21	30.25	.....	9.9	.....	46	19	18	−24	29	2	46	.....	.....	.....	0.41	−0.5	7	9,049	nw.	44	nw.	24	6	10	15	6.7	6.2	1.8
St. Paul	837	201	236	29.30	30.27	+0.19	10.1	−9.2	45	19	18	−22	29	2	45	.....	.....	.....	0.57	−0.5	12	9,261	nw.	44	nw.	24	4	14	13	6.5	7.1	2.0
La Crosse	714	11	48	29.45	30.27	+ .19	12.4	−10.4	39	20	20	−16	29	5	38	.....	.....	.....	0.42	−0.9	7	4,644	nw.	23	nw.	24	8	5	18	6.7	5.7	1.0
Madison	974	70	78	29.16	30.28	+ .20	13.9	−8.8	42	24	20	−15	29	8	38	13	10	81	0.45	−1.3	10	7,957	nw.	33	s.	17	6	7	18	7.0	4.8	0.8
Wausau	1,247	4	....	28.81	30.22	.....	10.4	.....	37	18	18	−21	29	2	40	.....	.....	.....	0.53	.....	9	.....	nw.	.....	.....	.....	11	6	14	5.6	6.4	1.7
Charles City	1,015	10	49	29.14	30.28	+ .18	11.5	−7.5	43	20	20	−18	29	4	36	11	8	86	0.44	−0.8	9	5,778	n.	24	s.	17	5	10	16	7.2	7.9	2.0
Davenport	606	71	79	29.59	30.30	− .20	18.2	−9.0	50	23	25	−11	29	11	31	16	13	81	0.68	−1.0	8	5,630	nw.	26	w.	9	6	8	17	7.1	9.0	2.6
Des Moines	861	84	97	29.31	30.27	+ .16	16.7	−9.0	54	20	25	−17	29	9	37	15	12	80	0.88	−0.4	9	6,085	n.	28	nw.	9	7	6	18	6.8	11.1	1.3
Dubuque	698	81	96	29.51	30.31	+ .21	15.8	−8.7	47	24	23	−14	15	9	36	14	11	81	0.52	−1.2	6	5,437	s.	23	n.	24	8	6	17	6.6	8.0	0.9
Keokuk	614	64	78	29.58	30.30	+ .18	20.9	−8.5	62	2	29	−14	29	13	31	18	14	78	0.36	−1.5	7	6,250	nw.	28	nw.	9	12	10	9	5.2	6.0	1.0
Cairo	356	87	93	29.87	30.27	+ .12	28.7	−9.8	69	2	37	−7	9	20	29	25	21	77	2.31	−1.0	9	7,552	n.	39	sw.	9	9	11	11	5.6	22.7	2.2
Peoria	609	11	45	29.59	30.29	+ .18	19.8	−8.3	54	20	28	−13	29	12	28	18	15	87	0.63	−1.7	10	5,813	n.	24	sw.	20	9	10	12	5.9	7.4	1.6
Springfield, Ill	644	10	91	29.56	30.27	+ .15	22.6	−8.7	61	2	30	− 8	29	15	24	20	16	79	0.75	−1.7	12	6,784	nw.	29	nw.	9	11	4	16	6.1	8.8	1.3
Hannibal	534	74	109	29.68	30.29	+ .17	22.3	−9.0	66	2	30	−11	29	14	30	.....	.....	.....	0.55	−1.1	6	7,004	sw.	31	sw.	20	11	7	13	5.7	7.3	1.2
St. Louis	567	265	303	29.64	30.28	+ .15	26.8	−8.7	66	2	34	− 4	10	20	25	23	20	79	0.78	−1.4	11	9,494	s.	38	sw.	20	5	11	15	6.5	7.5	1.3
Missouri Valley.							19.0	−7.9													80	0.52	−0.5									6.4		
Columbia, Mo	781	11	84	29.39	30.27	+0.15	24.0	−8.9	72	2	32	−9	10	16	36	.....	.....	.....	0.44	−1.6	4	6,742	se.	30	nw.	9	5	9	17	6.8	4.5	0.2
Kansas City	963	161	181	29.18	30.26	+ .14	23.4	−8.1	68	1	31	−9	29	16	36	21	16	73	0.45	−0.9	4	9,499	n.	49	nw.	9	10	9	12	5.6	5.3	0.5
St. Joseph	967	11	49	29.19	30.28	.....	21.8	.....	62	1	30	−13	29	13	32	19	15	78	0.16	.....	5	6,847	n.	42	nw.	9	4	13	14	6.4	2.5	T.
Springfield, Mo	1,324	98	104	28.79	30.26	+ .13	26.5	−9.0	71	2	35	−9	8	18	29	23	20	79	1.18	−1.5	3	8,511	s.	48	n.	9	10	14	7	5.0	16.1	0
Iola	984	11	50	29.16	30.26	+ .14	25.4	−7.1	69	2	34	−8	8	17	33	.....	.....	.....	0.29	−0.6	3	6,466	s.	33	nw.	9	8	8	15	6.3	2.6	0.0
Topeka	983	85	101	.....	.....	.....	23.8	−7.3	70	1	33	−9	29	15	39	.....	.....	.....	0.19	−0.7	3	7,658	n.	42	nw.	9	6	14	11	5.7	2.7	0.2
Drexel	1,299	10	54	28.80	30.26	.....	16.0	.....	51	1	25	−23	29	7	30	13	11	88	0.33	.....	8	8,500	n.	36	sw.	17	5	10	16	6.9	6.4	0.1
Lincoln	1,189	11	84	28.92	30.26	+ .14	18.6	−8.3	58	18	28	−18	29	9	30	16	12	79	0.23	−0.4	4	8,062	n.	44	n.	9	7	9	15	6.6	.5	T.
Omaha	1,105	115	122	29.03	30.28	+ .17	18.0	−9.1	53	1	26	−20	29	10	30	16	11	74	0.48	−0.4	7	7,190	s.	38	n.	24	6	9	16	6.5	6.8	0.5
Valentine	2,598	47	54	27.38	30.24	+ .14	18.2	−6.3	68	1	31	−25	8	5	49	15	12	84	0.45	−0.2	13	6,590	w.	42	nw.	9	8	11	12	6.2	4.4	T.
Sioux City	1,135	94	164	28.99	30.28	+ .16	13.6	−9.0	47	1	22	−28	29	5	33	12	9	83	0.68	−0.1	7	9,546	s.	51	nw.	9	7	11	13	6.0	7.2	1.6
Huron	1,306	59	74	28.81	30.30	+ .20	9.7	−6.0	50	19	20	−33	29	0	40	7	4	83	0.30	−0.3	11	8,657	se.	36	nw.	9	5	8	18	6.9	4.0	1.0
Pierre	1,572	70	75	28.51	30.28	+ .18	13.1	−7.0	53	19	23	−27	29	3	45	10	6	76	0.72	+0.2	13	6,440	nw.	42	nw.	9	3	14	14	6.5	9.9	1.4
Yankton	1,233	49	57	28.87	30.28	+ .17	13.8	−8.4	53	19	24	−32	29	4	39	.....	.....	.....	0.77	0.0	11	6,062	nw.	32	nw.	27	4	12	15	7.5	10.1	3.0

TABLE I.—*Climatological data for Weather Bureau stations, December, 1917*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation.			Wind.					Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sealevel, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F*		°*F*	°*F.*		°*F*	°*F.*		°*F.*	°*F.*	%	*In.*	*In.*		*Miles.*								*0–10*	*In.*	*In.*
Northern Slope.							**22.5**	**−1.5**											**74**	**1.97**	**+1.1**									**7.4**		
Billings	3,140	5		27.40	30.20	+0.15	20.9		61	1	30	−12	10	12	48					1.54		12		ne.				5	16	10		20.7	T.
Havre	2,505	11	44	27.40	30.20	+0.15	8.4	−12.8	50	18	17	−25	12	0	42	8	6	86		2.64	+2.0	20	5,737	e.	38	sw.	16	3	8	20	7.7	26.1	4.0
Helena	4,110	87	112	25.75	30.09	− .04	24.2	−0.6	59	18	35	−23	12	14	51	21	18	78		3.28	+2.5	20	5,739	sw.	56	sw.	17	0	11	20	7.9	31.2	T.
Kalispell	2,962	11	34	26.87	30.01	− .06	26.2	+2.3	53	18	33	−4	12	20	31	25	22	85		4.78	+2.9	24	3,653	nw.	33	nw.	11	2	5	24	8.6	26.8	4.5
Miles City	2,371	48	55	27.56	30.25	+ .15	13.2	−7.8	50	1	22	−22	9	5	38	11	7	79		2.50	+1.9	17	4,117	ne.	32	nw.	8	2	19	10	6.2	20.0	7.6
Rapid City	3,259	50	58	26.64	30.23	+ .14	19.4	−6.6	64	19	32	−21	12	7	53	15	9	70		0.71	+0.2	12	6,359	n.	48	n.	23	4	12	15	6.9	6.5	T.
Cheyenne	6,088	84	101	23.95	30.05	− .04	30.4	−1.4	59	1	42	−7	9	19	42	26	17	58		0.81	+0.5	7	13,629	w.	62	w.	20	3	13	15	6.9	12.1	0.0
Lander	5,372	60	68	24.61	30.10	− .05	30.2	+11.0	62	19	44	−4	13	16	52	23	15	59		0.42	−0.3	2	3,795	sw.	44	w.	22	5	18	8	5.8	4.8	0.0
Sheridan	3,790	10	47	26.10	30.17	.....	21.2	.....	64	1	34	−17	12	8	51	16	12	76		1.02	.....	14	3,709	nw.	36	sw.	1	1	5	25	8.9	14.5	0.7
Yellowstone Park	6,200	11	48	23.82	30.07	+ .09	27.2	+5.6	45	30	34	−6	12	20	36	26	22	75		2.28	+0.5	22	7,781	s.	37	sw.	23	1	5	22	8.8	14.5	T.
North Platte	2,821	11	51	27.18	30.25	+ .15	23.7	−2.9	68	23	37	−12	9	11	48	17	13	76		0.27	−0.2	5	5,187	w.	40	nw.	9	6	13	15	6.2	3.6	0.0
Middle Slope.							**30.5**	**−2.4**											**68**	**1.43**	**−0.6**									**5.0**		
Denver	5,292	106	113	24.72	30.09	+0.01	38.0	+5.8	67	19	53	0	10	23	48	28	19	56		0.27	−0.3	2	5,856	s.	34	n.	9	5	21	5	5.7	4.3	0.0
Pueblo	4,685	80	86	25.31	30.11	+ .03	35.4	+3.7	72	30	52	−2	8	18	49	26	14	49		0.03	−0.4	1	4,668	nw.	34	nw.	30	9	17	5	4.7	0.4	0.0
Concordia	1,392	50	58	28.73	30.28	+ .17	23.5	−6.0	73	1	34	−9	29	13	46	19	17	85		0.06	−0.4	4	6,398	s.	44	nw.	9	9	11	11	5.8	0.6	0.0
Dodge City	2,509	11	51	27.51	30.23	+ .13	28.2	−3.4	75	1	41	−7	8	15	58	20	13	63		0.25	−0.3	1	7,548	n.	41	n.	24	14	13	4	3.7	2.5	0.0
Wichita	1,358	139	158	28.73	30.23	+ .12	26.4	−7.8	71	1	36	−5	8	17	35	23	20	79		0.21	−0.6	1	10,427	s.	45	n.	9	9	16	6	5.5	2.1	0.0
Altus	1,410	5	.....	.....	.....	.....	34.6	.....	80	1	45	6	8	24	45	.....	.....	.....		T.	.....	0	.....	n.	.....	.....	.....	19	0	12	.....	0.0	0.0
Muskogee	652	4	.....	.....	.....	.....	32.6	.....	75	1	43	−2	8	22	37	.....	.....	.....		0.32	.....	1	.....	n.	.....	.....	.....	13	1	17	.....	3.2	0.0
Oklahoma	1,214	10	47	28.90	30.24	+ .13	31.6	−7.0	73	2	41	1	8	22	29	27	22	73		0.04	−1.7	1	10,255	n.	48	n.	9	15	7	9	4.6	0.4	0.0
Southern Slope.							**42.3**	**−1.5**											**53**	**0.02**	**−0.8**									**2.5**		
Abilene	1,738	10	52	28.32	30.19	+0.08	40.3	−4.7	82	1	53	8	29	28	43	32	23	57		0.01	−1.1	1	7,165	s.	32	nw.	7	15	11	5	3.9	0.0	0.0
Amarillo	3,676	10	49	26.32	30.16	+ .03	36.1	−0.3	77	1	52	1	8	20	58	27	20	65		0.04	−0.8	1	7,814	n.	34	nw.	7	29	1	1	2.6	0.4	0.0
Del Rio	944	64	71	29.16	30.17	+ .07	50.5	−1.9	83	4	62	22	30	39	38	.....	.....	.....		0.03	−0.9	2	5,551	e.	47	nw.	7	14	10	7	2.3	0.0	0.0
Roswell	3,566	75	85	26.43	30.11	+ .04	42.2	+1.0	73	2	60	6	8	24	50	30	14	38		0.00	−0.6	0	4,922	s.	44	nw.	7	27	4	0	1.3	0.0	0.0
Southern Plateau.							**50.4**	**+4.7**											**40**	**T.**	**−0.6**									**1.1**		
El Paso	3,762	116	133	26.27	30.08	+0.05	49.6	+4.8	72	1	65	24	8	35	41	37	20	32		0.00	−0.5	0	6,084	nw.	41	nw.	7	30	1	0	0.7	0.0	0.0
Santa Fe	7,013	57	66	23.28	30.11	+ .05	38.2	+7.9	56	1	49	13	8	27	28	28	18	48		0.02	−0.7	1	5,948	n.	26	n.	26	23	8	6	2.6	0.7	0.0
Flagstaff*	6,908	8	57	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....		.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Phoenix	1,108	11	81	28.90	30.03	+ .04	54.6	+2.7	80	29	73	29	8	36	44	41	28	43		0.00	−0.6	0	3,051	e.	19	n.	7	28	2	1	1.0	0.0	0.0
Yuma	141	9	54	29.92	30.07	+ .02	59.0	+3.3	82	29	75	40	11	43	36	45	29	37		0.00	−0.4	0	3,507	n.	31	n.	7	29	1	1	0.7	0.0	0.0
Independence*	3,910	11	42	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....		.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Needles	488	4	.....	29.56	30.07	.....	52.0	.....	76	29	67	30	12	37	39	.....	.....	.....		0.00	.....	0	.....	nw.	.....	.....	.....	28	1	2	.....	0.0	0.0
Middle Plateau.							**38.1**	**+6.8**											**57**	**0.17**	**−0.8**									**4.8**		
Reno	4,532	74	81	25.60	30.23	+0.08	41.2	+7.5	67	19	55	20	12	27	40	33	25	58		0.27	−1.4	2	3,242	w.	48	w.	1	17	9	3	3.7	T.	0.0
Tonopah	6,090	12	20	24.18	30.18	.....	40.6	.....	58	19	48	19	7	34	24	32	22	48		0.00	−0.8	0	4,490	w.	39	nw.	6	20	6	4	3.2	0.0	0.0
Winnemucca	4,344	18	56	25.75	30.23	+ .05	37.2	+6.5	65	19	53	6	11	22	46	30	22	59		0.05	−0.9	1	5,198	sw.	35	sw.	1	11	5	15	5.5	T.	0.0
Modena	5,479	10	43	24.72	30.19	+ .07	36.1	+4.4	65	30	52	9	8	26	43	27	18	57		0.20	−0.4	1	6,799	w.	29	n.	6	18	5	8	3.9	1.6	0.0
Salt Lake City	4,360	163	203	25.72	30.16	+ .01	41.8	+9.7	61	19	49	26	8	33	24	35	28	58		0.38	−1.0	5	3,908	se.	33	w.	1	5	8	18	7.4	2.7	0.0
Grand Junction	4,602	82	96	25.51	30.18	+ .08	34.0	+5.8	57	2	46	14	12	22	33	28	20	62		0.12	−0.3	3	3,218	nw.	26	w.	10	12	13	6	4.9	0.5	0.0
Northern Plateau.							**41.4**	**+9.3**											**74**	**2.50**	**+0.8**									**8.4**		
Baker	3,471	48	53	26.48	30.12	−0.04	39.0	+11.6	58	29	45	19	7	33	20	36	32	77		1.14	−0.4	15	4,973	se.	26	s.	17	0	7	24	8.0	0.5	0.0
Boise	2,739	78	86	27.28	30.18	− .02	43.2	+11.0	64	29	50	23	7	36	25	39	34	71		2.33	+0.6	17	3,268	se.	20	se.	15	2	5	24	8.6	T.	0.0
Lewiston	757	40	48	29.22	30.05	− .08	43.4	+5.9	66	18	50	27	24	37	22	.....	.....	.....		3.99	+2.5	21	2,614	e.	24	w.	11	0	5	26	9.1	0.8	0.0
Pocatello	4,477	60	68	25.53	30.12	− .07	40.0	+11.6	57	19	46	22	3	34	24	35	29	67		0.55	−0.3	8	11,015	sw.	50	sw.	12	3	9	19	7.6	0.5	0.0
Spokane	1,929	101	110	27.94	30.04	− .04	36.4	+5.6	58	29	42	14	24	31	22	34	32	83		2.85	+0.2	19	6,296	sw.	42	sw.	17	2	4	25	8.6	8.7	0.0
Walla Walla	991	57	65	28.99	30.08	− .04	46.1	+10.1	67	18	52	20	24	40	21	42	37	71		4.11	+2.0	21	4,877	s.	30	sw.	11	1	5	22	9.0	T.	0.0
North Pacific Coast Region.							**46.6**	**+4.5**											**89**	**12.29**	**+4.9**									**9.0**		
North Head	211	11	56	29.82	30.05	+0.02	47.4	+3.1	60	30	50	35	23	44	13	47	47	97		13.22	+5.7	28	16,689	s.	84	s.	15	1	1	29	9.5	0.0	0.0
North Yakima	1,071	4	.....	.....	.....	.....	38.0	.....	62	29	46	19	7	30	31	.....	.....	.....		1.96	.....	11	.....	nw.	.....	.....	.....	8	4	19	.....	3.4	0.0
Port Angeles	53	8	48	29.99	30.02	.....	41.4	.....	56	31	46	23	24	36	16	.....	.....	.....		11.44	+6.3	21	4,576	s.	33	nw.	16	0	0	31	9.8	1.7	0.0
Seattle	125	213	250	29.92	30.05	+ .04	45.0	+3.8	61	28	49	29	24	41	17	43	41	88		9.21	+3.2	21	9,588	s.	52	sw.	18	2	0	29	9.3	0.0	0.0
Tacoma	213	113	120	29.82	30.05	+ .04	45.8	+5.5	62	29	50	28	24	41	19	45	44	94		15.31	+8.0	22	6,254	sw.	30	sw.	15	1	2	28	9.3	T.	0.0
Tatoosh Island	109	7	57	29.88	29.98	+ .02	44.8	+0.9	58	31	48	34	24	41	14	44	42	90		18.91	+4.3	28	16,123	e.	68	s.	15	2	4	25	8.8	T.	0.0
Medford	1,425	4	.....	.....	.....	.....	41.7	.....	58	26	47	27	8	37	20	.....	.....	.....		2.75	.....	12	.....	se.	.....	.....	.....	4	12	15	.....	0.0	0.0
Portland, Oreg.	153	68	106	29.94	30.10	+ .03	48.4	+7.1	65	29	52	34	25	44	24	46	44	82		14.23	+6.9	26	6,581	sw.	32	s.	18	0	3	28	9.3	0.0	0.0
Roseburg	510	9	57	29.63	30.18	+ .07	48.4	+6.5	67	27	54	29	3	43	18	46	44	85		3.71	−2.2	14	1,684	s.	16	s.	15	0	17	14	7.1	0.0	0.0
Middle Pacific Coast Region.							**52.0**	**+3.5**											**74**	**0.88**	**−0.4**									**4.4**		
Eureka	62	73	89	30.13	30.20	+0.08	51.2	+3.2	67	27	58	36	7	45	20	49	47	87		1.17	−6.1	9	3,679	se.	38	nw.	1	12	6	13	5.6	0.0	0.0
Mount Tamalpais	2,375	11	18	27.66	30.15	+ .03	52.7	+5.1	72	31	57	39	3	48	15	45	36	59		1.22	−2.7	5	10,137	n.	52	nw.	14	20	5	6	3.5	0.0	0.0
Point Reyes Light	490	7	18	29.60	30.12	.....	54.6	+4.0	68	29	60	45	2	50	19	.....	.....	.....		0.82	.....	3	11,052	n.	70	s.	23	17	8	6	4.1	0.0	0.0
Red Bluff	332	50	56	29.82	30.19	+ .05	50.3	+3.9	72	28	59	32	14	41	31	45	39	72		1.17	−3.3	3	3,079	nw.	26	nw.	7	17	5	9	4.2	0.0	0.0
Sacramento	69	106	117	30.12	30.19	+ .05	49.2	+2.9	68	27	57	32	15	41	32	46	41	77		0.45	−3.1	2	3,594	n.	25	se.	26	14	2	15	5.2	0.0	0.0
San Francisco	155	209	213	29.99	30.16	+ .04	54.6	+3.7	68	12	61	43	22	49	21	50	46	77		0.72	−3.5	3	4,127	n.	24	se.	25	17	9	5	3.4	0.0	0.0
San Jose	141	12	110	30.00	30.16	.....	51.6	+1.7	68	12	62	32	10	41	36	.....	.....	.....		0.55	−2.5	2	3,127	nw.	31	n.	7	12	8	10	4.6	0.0	0.0
South Pacific Coast Region.							**57.5**	**+4.5**											**64**	**0.09**	**−2.0**									**2.9**		
Fresno	327	80	98	29.82	30.19	+0.06	49.7	+2.9	66	28	60	32	15	39	30	44	39	70		0.14	−1.4	3	2,753	nw.	26	nw.	1	18	6	7	4.0	0.0	0.0
Los Angeles	338	159	191	29.72	30.09	+ .02	62.8	+6.3	86	29	74	45	12	52	29	51	43	59		0.07	−2.8	1	3,670	sw.	15	s.	8	24	5	2	2.2	0.0	0.0
San Diego	87	62	70	29.98	30.07	.00	58.6	+2.9	78	29	68	44	12	49	28	51	45	70		T.	−1.8	0	3,075	nw.	17	nw.	27	23	7	1	2.2	0.0	0.0
San Luis Obispo	201	32	40	29.92	30.13	+ .02	58.8	+6.0	87	29	72	31	11	45	45	49	40	57		0.14	−2.2	2	2,930	nw.	22	n.	6	18	7	6	3.1	0.0	0.0
West Indies.																																	
San Juan, P. R	82	8	54	29.87	29.96	−0.01	74.7	.....	84	7	80	62	29	69	16	.....	.....	.....		3.01	−3.1	21	9,363	ne.	40	ne.	25	11	14	6	4.8	0.0	0.0
Panama Canal.																																	
Balboa Heights	118	7	97	29.76	29.88	.....	78.4	.....	89	11	86	68	29	71	18	73	72	90		4.09	−0.4	12	5,760	nw.	25	n.	30	2	24	5	5.5	0.0	0.0
Colon	36	30	97	29.84	29.88	.....	77.6	.....	84	12	81	69	30	74	12	74	73	85		11.66	−0.2	22	9,190	n.	35	n.	30	2	19	10	6.5	0.0	0.0
Alaska.																																	
Juneau	80	11	49	.....	.....	.....	14.6	.....	37	31	18	−2	24	11	16	13	6	70		6.37	.....	21	5,867	ne.	30	ne.	12	5	1	25	8.2	31.1	26.0

* No report.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during December, 1917, at all stations furnished with self-registering gages.*

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Abilene, Tex.	21			T.														T.			
Albany, N. Y.	13–14			1.01														*			
Alpena, Mich.	7–8			0.46														*			
Amarillo, Tex.	7			0.04														*			
Anniston, Ala.	11			0.55														*			
Asheville, N. C.	8			0.45														0.18			
Atlanta, Ga.	8			0.18														0.12			
Atlantic City, N. J.	8			0.57														0.31			
Augusta, Ga.	25			0.35														0.18			
Baker, Oreg.	25–26			0.34														*			
Baltimore, Md.	8			0.86														0.22			
Bentonville, Ark.	7			0.66														*			
Binghamton, N. Y.	13–14			0.98														*			
Birmingham, Ala.	4			0.27														0.24			
Bismarck, N. Dak.	26			0.23														*			
Block Island, R. I.	8			0.67														0.40			
Boise, Idaho.	25			0.19														0.10			
Boston, Mass.	8			0.55														0.28			
Buffalo, N. Y.	8–9			1.40														*			
Burlington, Vt.	13–14			0.48														*			
Cairo, Ill.	7–8			1.65														*			
Canton, N. Y.	8–9			0.80														*			
Charles City, Iowa.	30			0.12														*			
Charleston, S. C.	6			0.39														0.11			
Charlotte, N. C.	4			0.50														0.50			
Chattanooga, Tenn.	25			0.35														0.21			
Cheyenne, Wyo.	9–10			0.48														*			
Chicago, Ill.	12–13			0.50														*			
Cincinnati, Ohio.	24			0.19														0.09			
Cleveland, Ohio.	8–9			0.50														*			
Columbia, Mo.	7			0.28														*			
Columbia, S. C.	26			0.36														0.21			
Columbus, Ohio.	8			0.57														*			
Concord, N. H.	1			1.11														*			
Concordia, Kans.	9			0.02														*			
Corpus Christi, Tex.	4			T.														T.			
Dallas, Tex.	18			0.01														0.01			
Davenport, Iowa.	12–13			0.15														*			
Dayton, Ohio.	8			0.57														*			
Del Rio, Tex.	21			0.02														0.01			
Denver, Colo.	10			0.22														*			
Des Moines, Iowa.	12			0.19														*			
Detroit, Mich.	8			0.51														*			
Devils Lake, N. Dak.	23			0.15														*			
Dodge City, Kans.	7			0.25														*			
Drexel, Nebr.	6–7			0.21														*			
Dubuque, Iowa.	12			0.34														*			
Duluth, Minn.	30			0.38														*			
Eastport, Me.	1–2			0.88														*			
Elkins, W. Va.	25			0.21														0.04			
Ellendale, N. Dak.	3–4			0.30														*			
El Paso, Tex.	‡			‡																	
Erie, Pa.	8–9			0.76														*			
Escanaba, Mich.	27			0.38														*			
Eureka, Cal.	1			0.22														0.18			
Evansville, Ind.	7–8			1.05														*			
Flagstaff, Ariz.																					
Fort Smith, Ark.	7			0.36														*			
Fort Wayne, Ind.	8			0.21														*			
Fort Worth, Tex.	17			T.														T.			
Fresno, Cal.	25			1.07														0.05			
Galveston, Tex.	11			0.57														0.18			
Grand Haven, Mich.	12–13			0.24														*			
Grand Junction, Colo.	2			0.04														0.04			
Grand Rapids, Mich.	9			0.20														*			
Green Bay, Wis.	30			0.08														*			
Greenville, S. C.	8			0.38														0.20			
Hannibal, Mo.	15			0.23														*			
Harrisburg, Pa.	8			1.25														*			
Hartford, Conn.	13–14			1.40														*			
Hatteras, N. C.	28			0.52														0.29			
Havre, Mont.	26–27			1.00														*			
Helena, Mont.	11–12			0.80														*			
Houghton, Mich.	8–9			1.88														*			
Houston, Tex.	7	6:20 p. m.	6:38 p. m.	0.43	6:20 p. m.	6:30 p. m.	0.00	0.26	0.42												
Huron, S. Dak.	13			0.06														*			
Independence, Cal.																					
Indianapolis, Ind.	8			0.45														*			
Iola, Kans.	7			0.24														*			
Jacksonville, Fla.	6			0.77														0.35			
Kalispell, Mont.	12–13			0.84														*			
Kansas City, Mo.	7			0.20														*			
Keokuk, Iowa.	15			0.14														*			
Key West, Fla.	22			0.07														0.07			
Knoxville, Tenn.	25			0.39														0.18			
La Crosse, Wis.	12			0.13														*			
Lander, Wyo.	9			0.32														*			
Lansing, Mich.	8			0.30														*			
Lewiston, Idaho.	11			0.14														0.12			
Lexington, Ky.	8			0.86														0.09			
Lincoln, Nebr.	6			0.10														*			
Little Rock, Ark.	25			0.08														0.07			
Los Angeles, Cal.	2			0.07														0.07			
Louisville, Ky.	7–8			1.31														*			
Ludington, Mich.	29–30			0.31														*			
Lynchburg, Va.	8			0.78														0.17			
Macon, Ga.	25			0.92														0.23			
Madison, Wis.	12–13			0.22														*			
Marquette, Mich.	6–7			0.95														*			
Memphis, Tenn.	7–8			1.10														*			
Meridian, Miss.	7	7:20 p. m.	D. N. p. m.	0.85	9:46 p. m.	10:08 p. m.	0.21	0.05	0.15	0.21	0.34	0.46									

* Self-register not in use. † Record partly estimated. ‡ No precipitation occurred during month.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during December, 1917, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Miami, Fla.	18			0.46														0.39			
Milwaukee, Wis.	12-13			0.63														*			
Minneapolis, Minn.	4			0.12														*			
Mobile, Ala.	7-8			0.57														0.52			
Modena, Utah	2			0.20														*			
Montgomery, Ala.	8			0.46														0.39			
Moorhead, Minn.	11			0.11														*			
Mount Tamalpais, Cal.	25			0.80														0.15			
Nantucket, Mass.	8			0.55														0.20			
Nashville, Tenn.	25			0.48														0.16			
New Haven, Conn.	13-14			1.55														*			
New Orleans, La.	25	11:30 a. m.	1:05 p. m.	0.60	11:54 a. m.	12:13 p. m.	0.03	0.22	0.36	0.45	0.51										
New York, N. Y.	8	10:17 a. m.	8:03 p. m.	1.41	5:52 p. m.	6:42 p. m.	0.32	0.06	0.12	0.21	0.31	0.38	0.47	0.57	0.67	0.79	0.91				
Norfolk, Va.	8			0.56														0.21			
Northfield, Vt.																					
North Head, Wash.	15			0.89														0.28			
North Platte, Nebr.	6			0.16														*			
Oklahoma, Okla.	7			0.04														*			
Omaha, Nebr.	6-7			0.16														*			
Oswego, N. Y.	13-14			0.45														*			
Palestine, Tex.	7			0.24														0.21			
Parkersburg, W. Va.	8			0.43														0.07			
Pensacola, Fla.	8	12:15 a. m.	2:40 a. m.	1.22	1:21 a. m.	1:51 a. m.	0.01	0.37	0.67	0.86	0.99	1.06	1.15								
Peoria, Ill.	13-14			0.22														*			
Philadelphia, Pa.	13-14			1.36														*			
Phoenix, Ariz.	‡			‡																	
Pierre, S. Dak.	27-28			0.28														*			
Pittsburgh, Pa.	8			0.42														*			
Pocatello, Idaho	1			0.23														0.15			
Point Reyes Light, Cal.	16			0.24														0.11			
Port Angeles, Wash.	15			1.16														0.24			
Port Huron, Mich.	13			0.36														*			
Portland, Me.	14			1.74														0.44			
Portland, Oreg.	14			0.73														0.37			
Providence, R. I.	8			0.86														*			
Pueblo, Colo.	7			0.03														*			
Raleigh, N. C.	8			0.59														0.27			
Rapid City, S. Dak.	23-24			0.20														*			
Reading, Pa.	13-14			1.39														*			
Red Bluff, Cal.	25-26			0.88														0.08			
Reno, Nev.	25			0.15														*			
Richmond, Va.	8			0.64														*			
Rochester, N. Y.	8-9			0.76														*			
Roseburg, Oreg.	19			0.41														0.16			
Roswell, N. Mex.	‡			‡																	
Sacramento, Cal.	25			0.41														0.12			
Saginaw, Mich.	8			0.36														*			
St. Joseph, Mo.	9			0.12														*			
St. Louis, Mo.	7-8			0.39														*			
St. Paul, Minn.	4			0.17														*			
Salt Lake City, Utah	2-3			0.17														*			
San Antonio, Tex.	2			T.														T.			
San Diego, Cal.	24			T.														T.			
Sand Key, Fla.	22			0.09														0.09			
Sandusky, Ohio	8			0.72														*			
Sandy Hook, N. J.	8			1.27														0.67			
San Francisco, Cal.	25			0.63														0.12			
San Jose, Cal.	1			0.43														*			
San Luis Obispo, Cal.	25			0.11														0.03			
Santa Fe, N. Mex.	7			0.02														*			
Sault Ste. Marie, Mich.	25-26			0.37														*			
Savannah, Ga.	5			0.47														0.46			
Scranton, Pa.	13-14			1.10														*			
Seattle, Wash.	27			0.42				*										0.21			
Sheridan, Wyo.	6-7			0.20														*			
Shreveport, La.	7			0.44														0.34			
Sioux City, Iowa	27-28			0.22														*			
Spokane, Wash.	25-26			0.50														*			
Springfield, Ill.	7			0.93														*			
Springfield, Mo.	7			0.93														*			
Syracuse, N. Y.	13-14			2.26														*			
Tacoma, Wash.	13-14			1.45														0.39			
Tampa, Fla.	5-6			0.24														0.20			
Tatoosh Island, Wash.	15			1.82														0.36			
Taylor, Tex.	18			0.02														0.01			
Terre Haute, Ind.	7-8			0.36														*			
Thomasville, Ga.	8			0.33														0.31			
Toledo, Ohio	8			0.53														*			
Tonopah, Nev.	‡			‡																	
Topeka, Kans.	7			0.12														*			
Trenton, N. J.	13-14			0.69														*			
Valentine, Nebr.	3			0.11														*			
Vicksburg, Miss.	7			1.07														0.42			
Walla Walla, Wash.	18-19			1.35														*			
Washington, D. C.	8			0.73														*			
Wausau, Wis.	4			0.19														*			
Wichita, Kans.	7			0.21														*			
Williston, N. Dak.	22-23			0.43														*			
Wilmington, N. C.	8			0.48														0.30			
Winnemucca, Nev.	27			0.05														0.03			
Wytheville, Va.	25-26			0.92														*			
Yankton, S. Dak.	27-28			0.23														*			
Yellowstone Park, Wyo.	1			0.38														*			

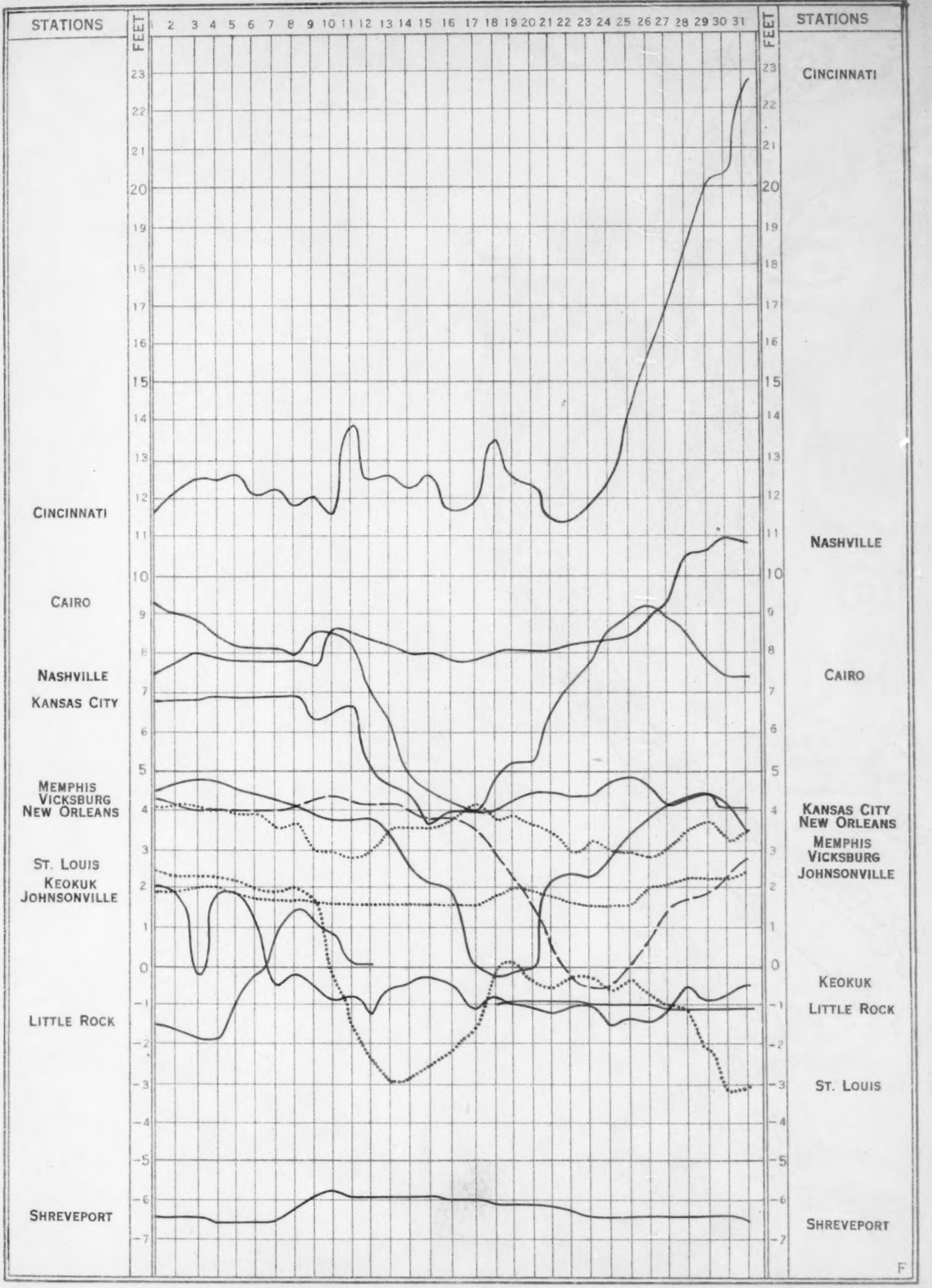
* Self-register not in use. † Record partly estimated. ‡ No precipitation occurred during month.

TABLE III.—*Data furnished by the Canadian Meteorological Service, December, 1917.*

Stations.	Altitude above M. S. L.* Jan., 1916.	Pressure.			Temperature.						Precipitation.		
		Station, reduced to mean of 24 hours.	Sealevel, reduced to mean of 24 hours.	Departure from normal.	Mean max.+ mean min.÷2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	*Inches.*	*Inches.*	*Inches.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*Inches.*	*Inches.*	*Inches.*
St. Johns, N. F.	125	29.88	30.02	+0.19	31.8	+3.1	36.5	27.1	49	7	5.61	+0.58	7.0
Sydney, C. B. I.	48	30.04	30.08	+ .19	27.7	−0.5	34.6	20.9	49	10	9.17	+4.54	46.5
Halifax, N. S.	88	29.99	30.10	+ .14	23.5	−4.1	31.7	15.3	50	−4	6.41	+1.29	33.4
Yarmouth, N. S.	65	30.02	30.10	+ .12	24.5	−6.2	31.5	17.5	51	1	3.39	−1.65	11.4
Charlottetown, P. E. I.	38	30.05	30.09	+ .15	21.6	−2.7	28.2	15.1	43	−4	4.87	+1.21	37.9
Chatham, N. B.	28	30.13	30.16	+0.22	12.9	−4.1	22.6	3.3	40	−20	2.15	−1.07	20.3
Father Point, Que.	20	30.15	30.18	+ .23	9.7	−5.7	17.6	1.9	38	−22	1.70	−1.13	17.0
Quebec, Que.	296	29.85	30.20	+ .19	7.5	−7.7	15.0	0.0	38	−32	3.67	−0.02	36.1
Montreal, Que.	187	30.00	30.33	+ .20	8.9	−9.4	16.0	1.9	38	−24	2.79	−0.86	20.9
Stonecliffe, Ont.	489	29.61	30.27	+ .26	4.2	−10.8	12.3	−3.8	36	−38	1.23	−1.26	11.3
Ottawa, Ont.	236	29.96	30.25	+0.23	7.6	−9.4	16.5	−1.4	40	−31	2.47	−0.44	23.2
Kingston, Ont.	285	29.90	30.24	+ .20	14.2	−9.5	22.6	5.8	45	−21	2.28	−0.96	18.5
Toronto, Ont.	379	29.78	30.21	+ .16	19.5	−7.5	26.6	12.4	42	−17	2.42	−0.49	23.0
White River, Ont.	1,244	28.75	30.16	+ .19	−3.2	−12.9	10.5	−16.9	35	−51	2.73	+1.02	27.3
Port Stanley, Ont.	592	29.56	30.24	+ .17	20.5	−7.9	27.4	13.6	42	− 8	1.55	−0.87	14.4
Southampton, Ont.	656	29.42	.....	.....	17.3	−9.4	24.4	10.2	39	−17	3.45	−0.53	31.3
Parry Sound, Ont.	688	29.47	30.22	+0.21	10.2	−11.0	19.4	1.0	39	−34	5.92	+1.44	51.4
Port Arthur, Ont.	644	29.46	30.23	+ .24	4.5	−8.7	15.0	−6.0	40	−34	1.03	+0.16	10.3
Winnipeg, Man.	760	29.40	30.31	+ .29	−3.7	−7.8	3.9	−11.3	28	−33	0.59	−0.32	5.9
Minnedosa, Man.	1,690	28.31	30.28	+ .26	−6.7	−12.4	2.8	−16.2	26	−40	1.31	+0.69	13.1
Qu' Appelle, Sask.	2,115	27.80	30.22	+0.22	−7.0	−14.4	2.6	−16.7	36	−36	1.42	+0.90	14.0
Medicine Hat, Alberta.	2,144	27.72	30.13	+ .16	4.9	−13.3	14.7	−4.9	46	−35	2.94	+2.39	29.4
Swift Current, Sask.	2,392	27.43	30.18	+ .19	1.4	−14.6	11.3	−8.4	47	−33	0.87	+0.09	8.7
Calgary, Alberta.	3,428	26.37	30.13	+ .19	5.1	−13.1	14.5	−4.2	55	−28	1.48	+0.89	14.8
Banff, Alberta.	4,521	25.23	30.05	+ .11	9.3	− 9.8	19.2	−0.6	44	−30	3.42	+2.21	31.5
Edmonton, Alberta.	2,150	27.72	30.19	+0.26	−6.8	−19.9	1.8	−15.4	34	−42	1.20	−0.50	12.0
Prince Albert, Sask.	1,450	28.60	30.30	+ .29	−13.0	−15.8	−4.6	−21.4	22	−50	0.99	+0.25	9.9
Battleford, Sask.	1,592	28.38	30.28	+ .29	−11.3	−16.7	−2.8	−19.8	27	−45	0.71	+0.39	7.1
Kamloops, B. C.	1,262	28.76	30 10	+ .16	21.6	−7.3	27.6	15.5	50	−11	2.74	+1.96	27.0
Victoria, B. C.	230	29.75	30.01	+ .04	41.3	+0.1	45.3	37.3	56	28	13.02	+5.04	4.0
Barkerville, B. C.	4,180	25.46	29.91	+0.03	12.5	−8.4	20.3	4.8	40	−21	4.69	+1.52	45.0
Hamilton, Bermuda.	151	29.88	30.05	− .07	63.6	−1.1	68.6	58.6	74	51	6.84	+2.35	0.0
LATE REPORTS—NOVEMBER, 1917.													
Medicine Hat, Alberta.	2,144	27.71	30.00	+0.03	43.8	+16.4	57.1	30.5	68	18	0.02	−0.90	0.2
Calgary, Alberta.	3,428	26.44	29.99	+ .01	42.9	+17.1	55.6	30.3	67	15	T.	−0.88	T.
Banff, Alberta.	4,521	25.44	30.09	+ .13	35.1	+9.3	43.5	26.7	56	16	0.30	−1.97	3.2
Edmonton, Alberta.	2,150	27.62	29.92	− .05	39.5	+16.6	51.0	28.1	66	13	0.18	−0.40	T.

* See Explanation of Tables, this REVIEW for July, p. 388.

Chart I. Hydrographs of Several Principal Rivers, December, 1917.



F

Chart II. Tracks of Centers of High Areas, December, 1917.

(Plotted by Charles A. Donnel.)

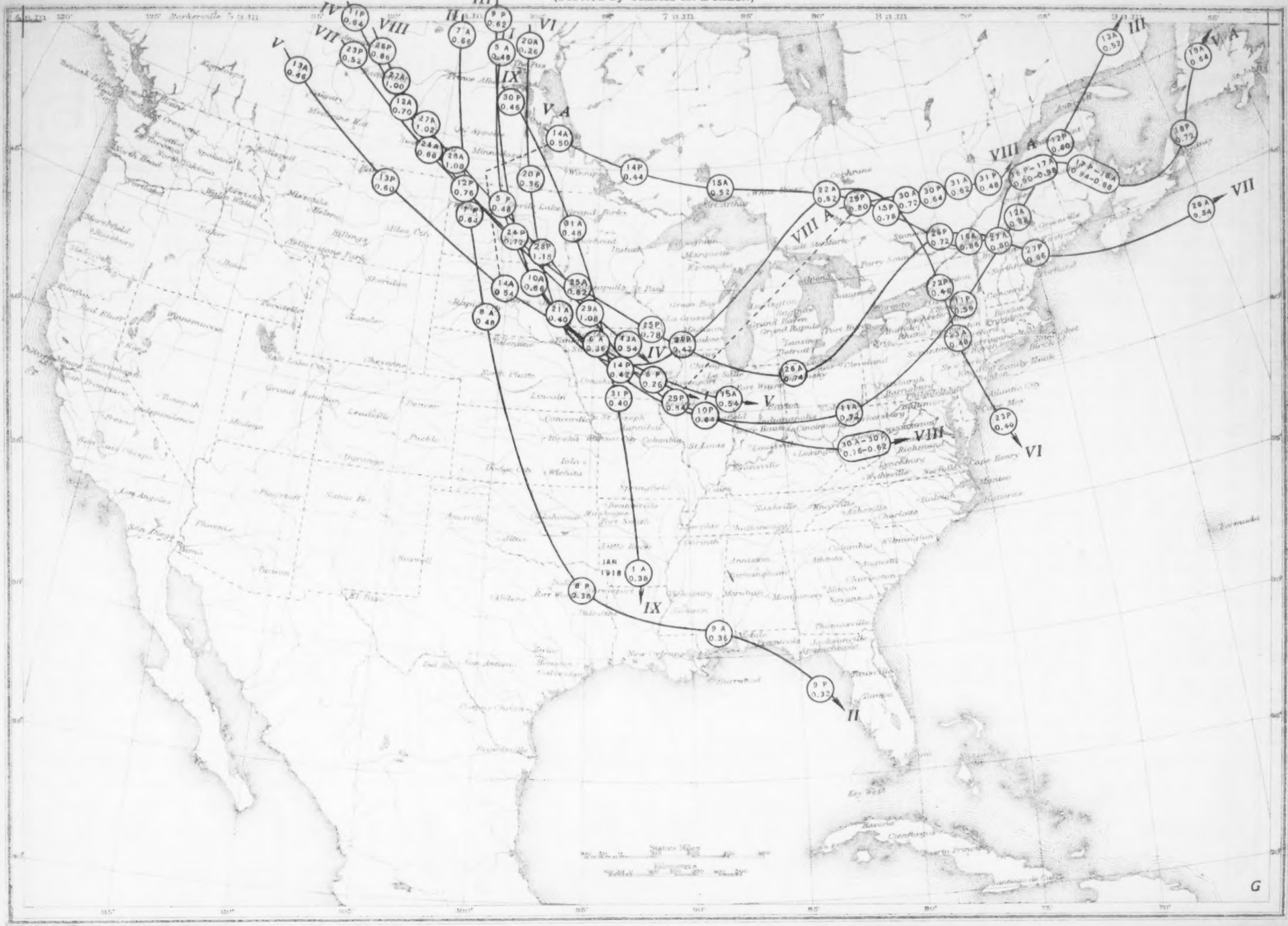


Chart III. Tracks of Centers of Low Areas, December, 1917.

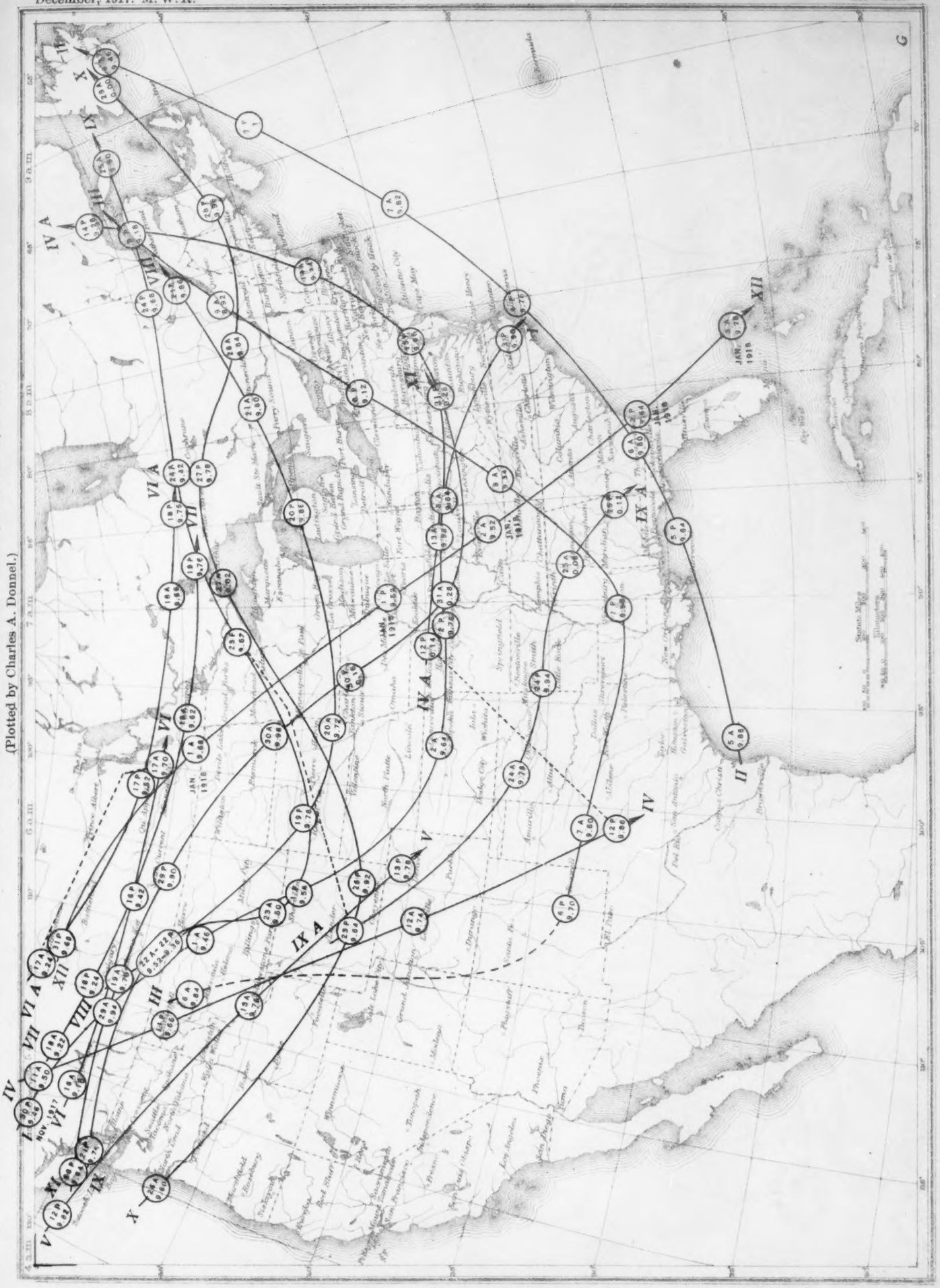


Chart III. Tracks of Centers of Low Areas, December, 1917.
(Plotted by Charles A. Donnel.)

Chart IV. Departure (°F.) of the Mean Temperature from the Normal, December, 1917.

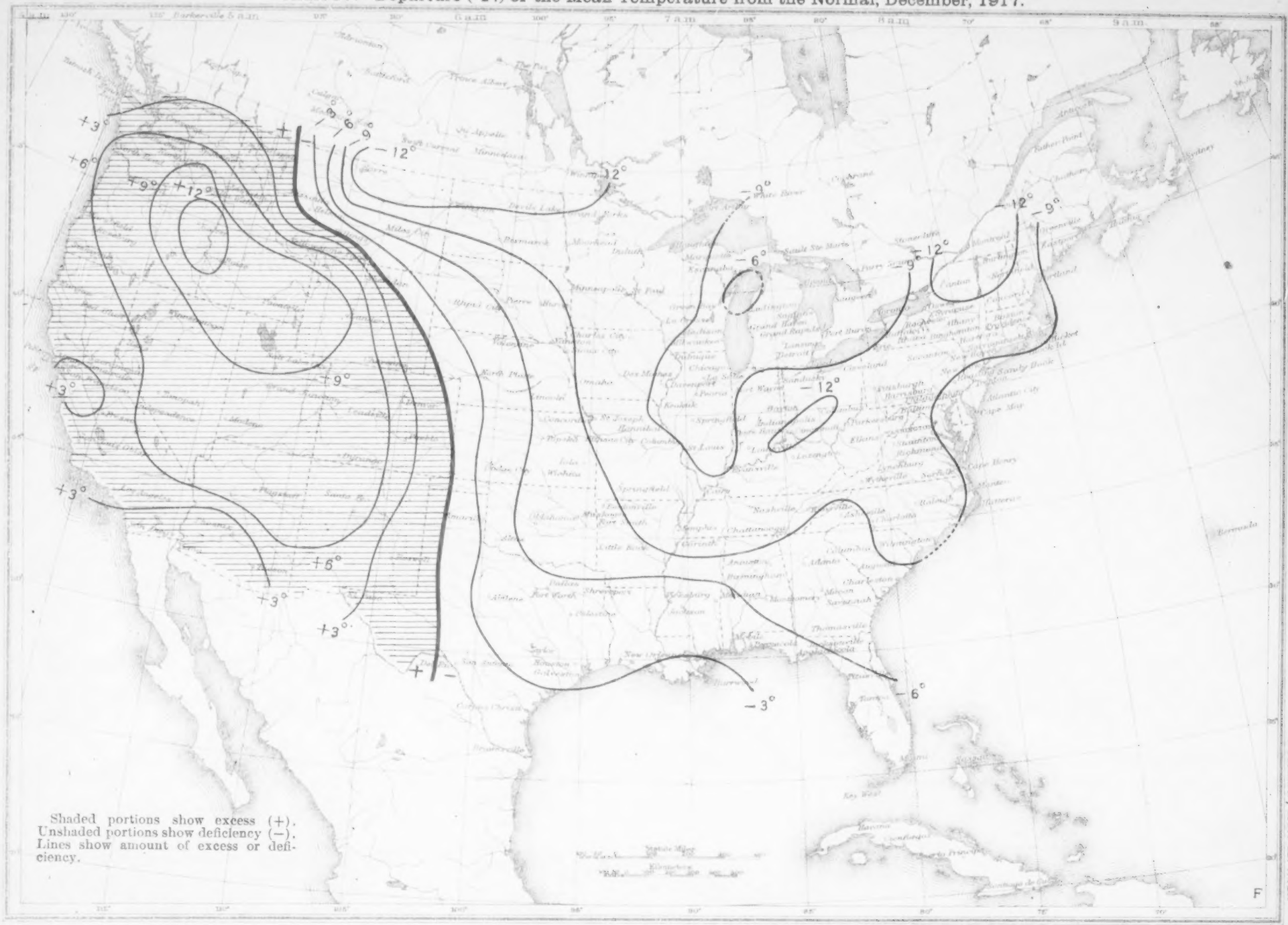


Chart V. Total Precipitation, December, 1917.

Chart VI. Percentage of Clear Sky between Sunrise and Sunset, December, 1917.

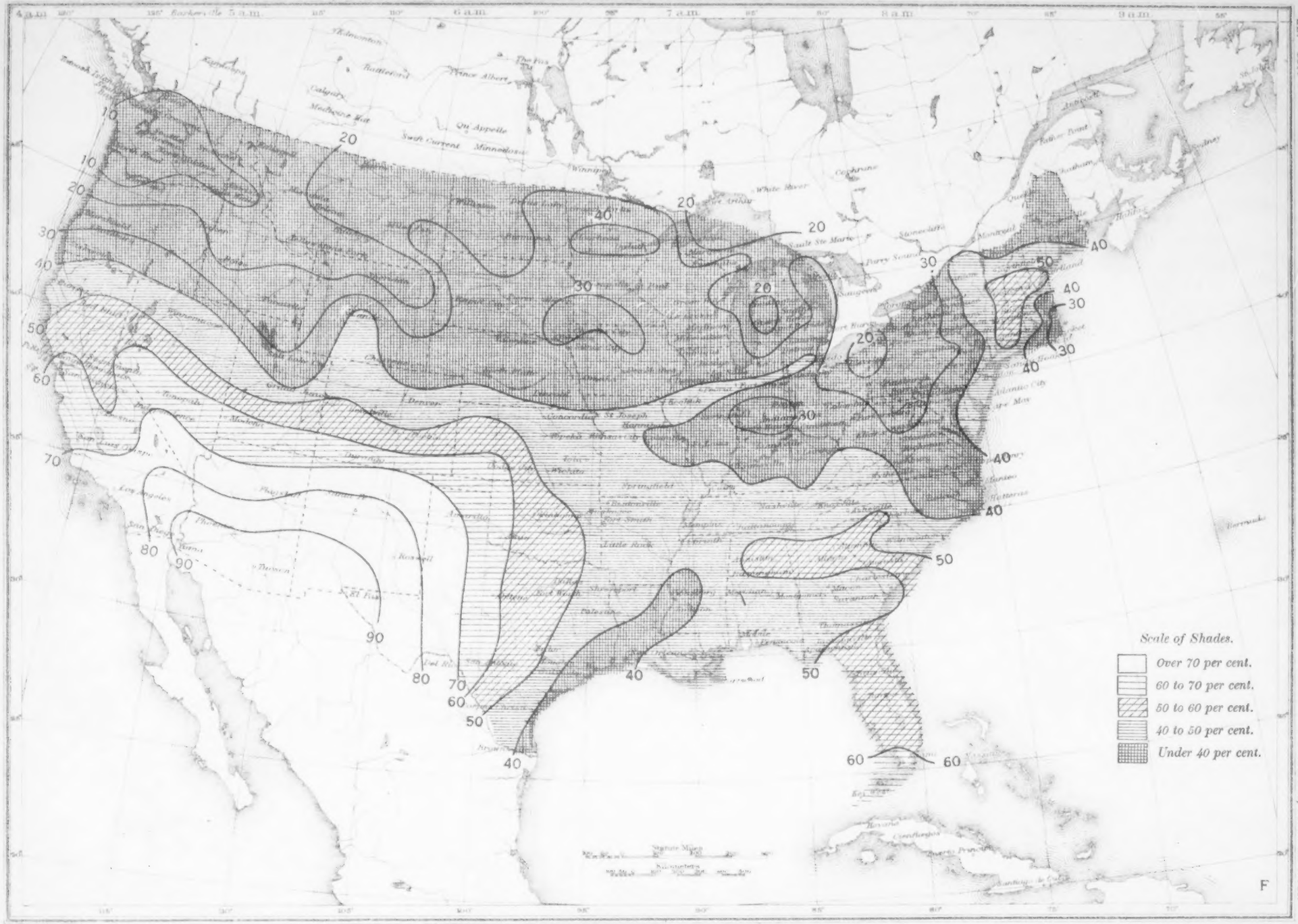


Chart VII. Isobars and Isotherms at Sea-level; Prevailing Winds, December, 1917.

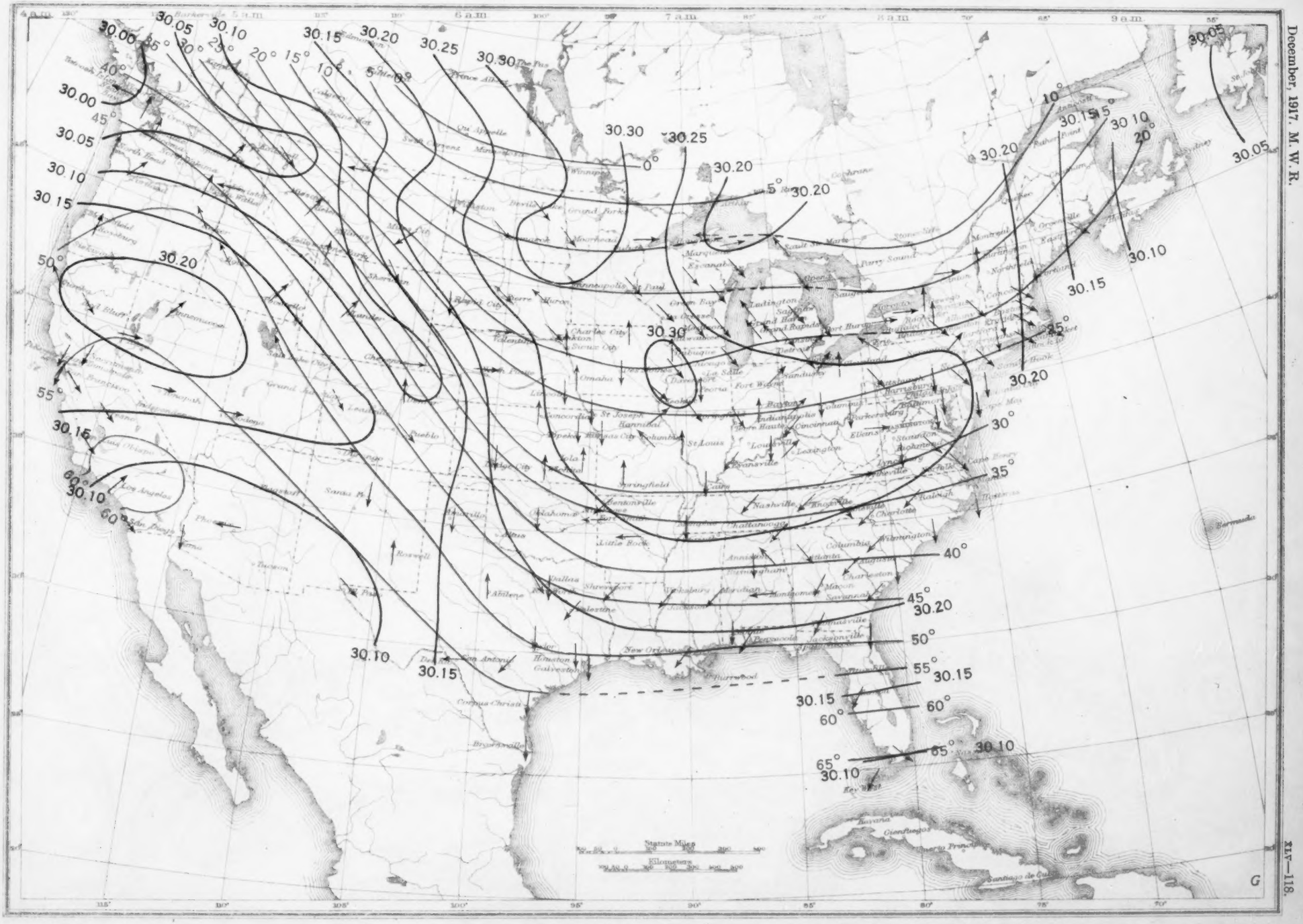


Chart VIII. Total Snowfall, Inches, December, 1917.

Chart IX. Means of Meteorological Data for North Atlantic Ocean, December, 1916.

Chart IX. Means of Meteorological Data for North Atlantic Ocean, December, 1916.

(Plotted by F. A. Young.)

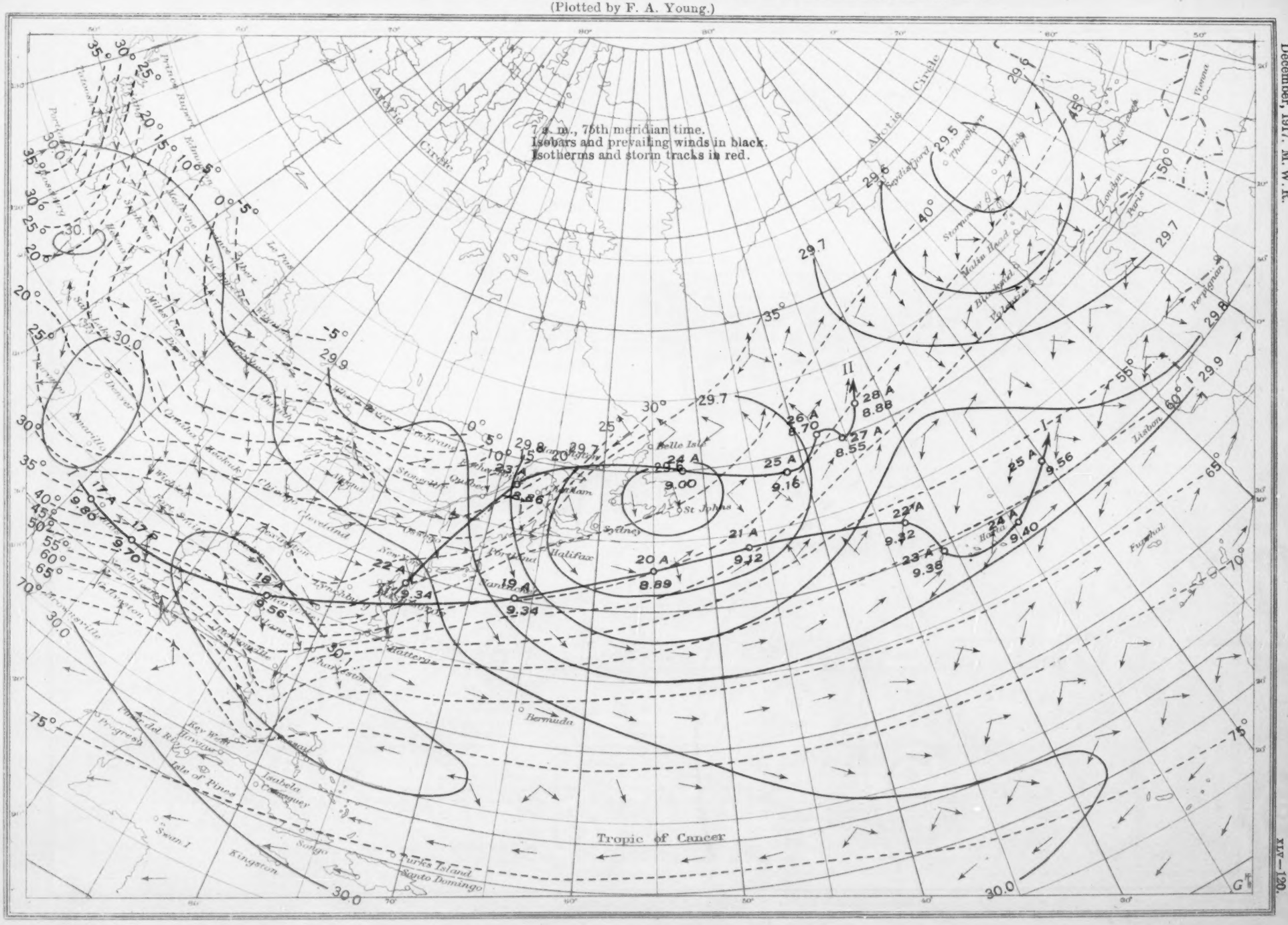


Chart X. Hurricanes of 1917.

(Plotted by C. A. Donnel.)

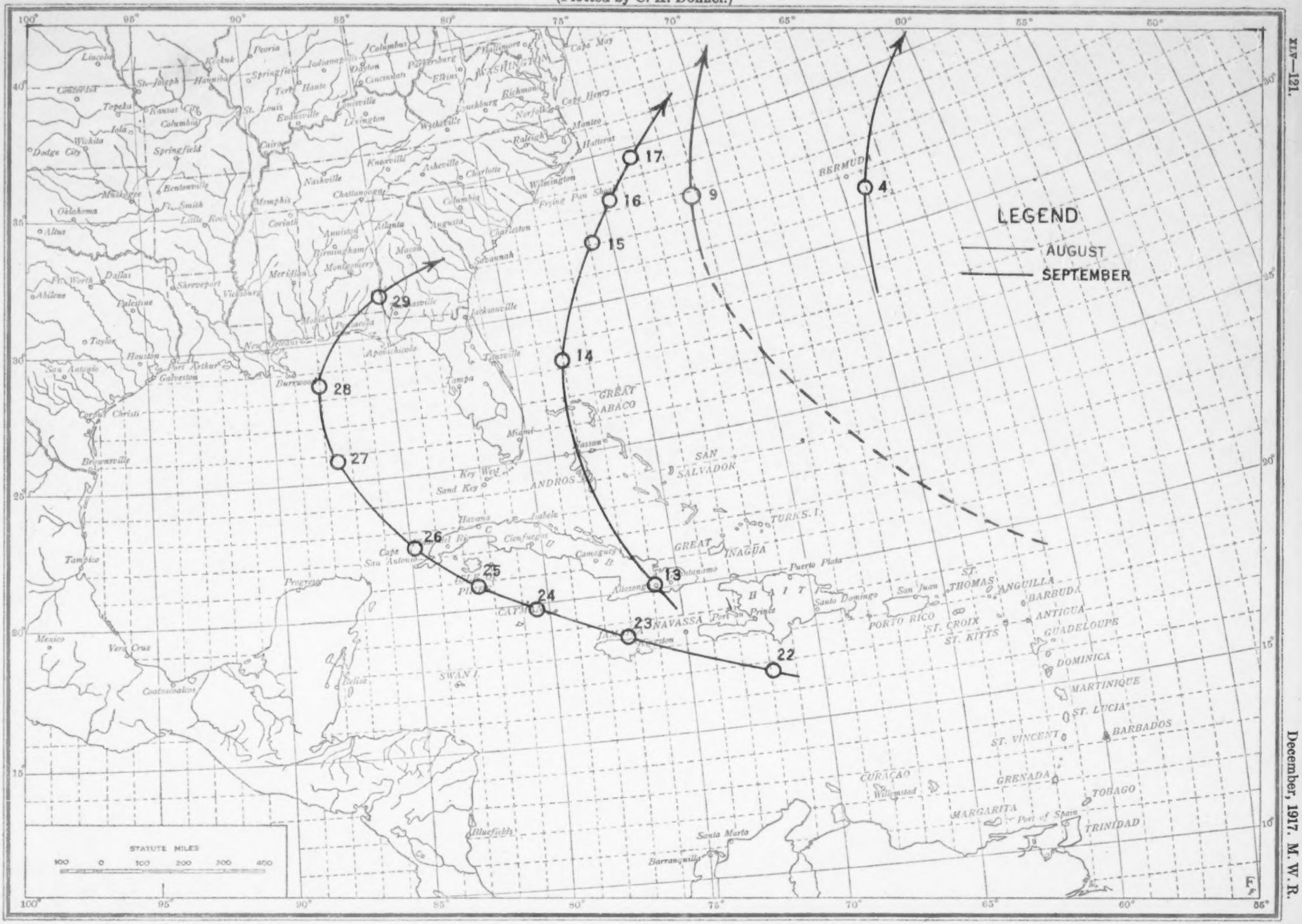

LEGEND
AUGUST
SEPTEMBER
STATUTE MILES
100 0 100 200 300 400
BERMUDA
GREAT ABACO
SAN SALVADOR
ANDROS
TURKS I.
GREAT INAGUA
NAVASSA
HAITI
PORTO RICO
ST. CROIX
ST. KITTS
ANGUILLA
BARBUDA
ANTIGUA
GUADELOUPE
DOMINICA
MARTINIQUE
ST. LUCIA
BARBADOS
ST. VINCENT
GRENADA
TOBAGO
TRINIDAD
CURAÇAO
MARGARITA
SWAN I.
Key West
Havana
Tampa
Miami
Nassau
Cape San Antonio
Progreso
Tampico
Vera Cruz
Coatzacoalcos
Bluefields
Santa Marta
Barranquilla
Puerto Plata
San Juan
Santo Domingo
Port au Prince
Port of Spain
Willemstad
Galveston
New Orleans
Pensacola
Jacksonville
Charleston
Savannah
Norfolk
Cape Henry
Cape May
Hatteras
Washington
Baltimore
Philadelphia
New York
Boston
Portland
Chicago
St. Louis
Memphis
Nashville
Atlanta
Birmingham
Montgomery
Vicksburg
Shreveport
Dallas
Houston
San Antonio
Corpus Christi
Brownsville
Wichita
Oklahoma
Kansas City
Omaha
Minneapolis
Duluth
Cincinnati
Louisville
Pittsburgh
Buffalo
Detroit
Cleveland
Toledo
Indianapolis
Springfield
Peoria
Milwaukee
Lincoln
Denver
Cheyenne
Salt Lake City
Pueblo
Albuquerque
El Paso
Phoenix
Los Angeles
San Francisco
Portland
Seattle
Spokane
Helena
Billings
Bismarck
Fargo
Sioux Falls
Des Moines
Kansas City
Topeka
Wichita
Oklahoma
Fort Worth
Abilene
Taylor
Palestine
Port Arthur
Galveston
Corpus Christi
Brownsville
Tampico
Mexico
Vera Cruz
Coatzacoalcos
Progreso
Cape San Antonio
Havana
Key West
Sand Key
Miami
Tampa
Apalachicola
Pensacola
Mobile
New Orleans
Vicksburg
Meridian
Shreveport
Dallas
Fort Worth
Houston
San Antonio
Galveston
Port Arthur
Corpus Christi
Brownsville
Tampico
Progreso
Mexico
Vera Cruz
Coatzacoalcos
Bluefields
Santa Marta
Barranquilla
Puerto Plata
San Juan
Santo Domingo
Port au Prince
Port of Spain
Willemstad
Nassau
Cape Henry
Norfolk
Richmond
Lynchburg
Cape May
Hatteras
Washington
Baltimore
Philadelphia
New York
Boston
Portland
Buffalo
Detroit
Cleveland
Toledo
Chicago
Milwaukee
Minneapolis
Duluth
Fargo
Bismarck
Billings
Helena
Spokane
Seattle
Portland
San Francisco
Los Angeles
Phoenix
El Paso
Albuquerque
Pueblo
Denver
Cheyenne
Salt Lake City
Omaha
Sioux Falls
Des Moines
Kansas City
St. Louis
Cincinnati
Louisville
Indianapolis
Springfield
Peoria
Lincoln
Columbus
Pittsburgh

Chart XI. Earthquakes of 1917.

DETAILED CLIMATOLOGICAL DATA.

Detailed climatological data for the United States and its colonies are collected and published in the monthly reports "Climatological Data" issued at the following Section Centers by the respective officials in charge. They may be secured from the *Superintendent of Documents, Government Printing Office, Washington, D. C.*

State.	Section center.	Official in charge.	State.	Section center.	Official in charge.
Alabama	Montgomery	Patrick H. Smyth.	New England	Boston	John W. Smith.
Arizona	Phoenix	Robert Q. Grant.	New Hampshire (see New England).		
Arkansas	Little Rock	Harvey S. Cole.	New Jersey	Trenton	G. Harold Noyes.
California	San Francisco	Edward A. Beals.	New Mexico	Santa Fe	Charles E. Linney.
Colorado	Denver	Frederick H. Brandenburg.	New York	Ithaca	Wilford M. Wilson.
Connecticut (see New England).			North Carolina	Raleigh	Lee A. Denson.
Delaware (see Maryland).			North Dakota	Bismarck	Orris W. Roberts.
District of Columbia (see Maryland).			Ohio	Columbus	W. H. Alexander.
Florida	Jacksonville	Alexander J. Mitchell.	Oklahoma	Oklahoma	J. Pemberton Slaughter.
Georgia	Atlanta	Charles F. von Hermann.	Oregon	Portland	Edward L. Wells.
Idaho	Boise	Clinton E. Norquest.	Pennsylvania	Philadelphia	George S. Bliss.
Illinois	Springfield	Clarence J. Root.	Rhode Island (see New England).		
Indiana	Indianapolis	John H. Armington.	South Carolina	Columbia	Richard H. Sullivan.
Iowa	Des Moines	George M. Chappel.	South Dakota	Huron	Montello E. Blystone.
Kansas	Topeka	Snowden D. Flora.	Tennessee	Nashville	Roscoe Nunn.
Kentucky	Louisville	Ferdinand J. Walz.	Texas	Houston	Bernard Bunnemeyer.
Louisiana	New Orleans	Isaac M. Cline.	Utah	Salt Lake City	J. Cecil Alter.
Maine (see New England).			Vermont (see New England).		
Maryland	Baltimore	Oliver L. Fassig.	Virginia	Richmond	Edward A. Evans.
Massachusetts (see New England).			Washington	Seattle	George N. Salisbury.
			West Virginia	Parkersburg	Henry C. Howe.
Michigan	Grand Rapids	Charles F. Schneider.	Wisconsin	Milwaukee	W. P. Stewart.
Minnesota	Minneapolis	Ulysses G. Purssell.	Wyoming	Cheyenne	L. H. Daingerfield.
Mississippi	Vicksburg	William E. Barron.			
Missouri	Columbia	George Reeder.			
Montana	Helena	William A. Mitchell.	Hawaiian Islands	Honolulu	Andrew M. Hamrick.
Nebraska	Lincoln	George A. Loveland.	Porto Rico	San Juan	F. Eugene Hartwell.
Nevada	Reno	Henry F. Alps.			

A monthly volume collecting all but the two last mentioned under one cover, is issued as above at 35 cents per copy, or subscription per year, 12 monthly copies and annual summary, at $4.

Single sections, 5 cents each.

SOME WEATHER BUREAU PUBLICATIONS.

A few of the more recent Weather Bureau publications are listed below, with their prices. A complete list may be obtained upon application to the *Chief, U. S. Weather Bureau.*

To secure such publications as have a price affixed, one should apply to and make remittances payable to the *Superintendent of Documents, Government Printing Office, Washington, D. C.* Stamps and personal checks are not accepted in payment. Additional charge for postage to foreign addresses.

National Weather and Crop Bulletin, with charts; monthly from October to March, weekly during the remainder of the year	25c. year.
Snow and Ice Bulletin, with charts, weekly during the winter	25c. season.
Climatological data, monthly for 42 separate sections; each section 5c. a copy	50c. a year.
Complete monthly number 42 sections	35c. each, $4.00 year.
Climatological data for the year 1916	25c.
Monthly Weather Review supplement No. 3. (Aerology No. 1)	25c.
Monthly Weather Review Supplement No. 4, "Types of anticyclones of the United States and their average movements"	**25c.**
Monthly Weather Review Supplement No. 5. (Aerology No. 2)	25c.
Monthly Weather Review Supplement No. 6, "Relative humidities and vapor pressures over the United States, including data from hygrometers"	**25c.**
Monthly Weather Review Supplement No. 7. (Aerology No. 3)	25c.
River stages at river gage stations on the principal rivers of the United States, Vol. XIV—1916	40c.
Weather forecasting in the United States	**$1.25**
Weather forecasting, with Introductory Notes on Atmospherics. (Bulletin No. 42, revised edition)	5c.
Papers on frost and frost protection in the United States	10c.
Instructions for cooperative observers, 5th ed. Circulars B and C combined	10c.
Instructions for the installation and operation of Class A evaporation stations. Circular L	10c.
Report of the Chief of the Weather Bureau, 1916–1917, (4° edition)	Free.
Brief list of meteorological text and reference books	**Free.**
Meteorological aspect of the smoke problem	Free.
Modern methods of protection against lightning. (Farmers' Bull. No. 842)	Free.
Rainfall and Gunfire, by A. Angot	**Free.**
Notes on the Climate of France and Belgium	**Free.**
The Weather Bureau. (Descriptive pamphlet)	Free.
West Indies Hurricane of Aug. 12–23, 1915. Chart with text	Free.
West Indies Hurricane of Sept. 22–Oct. 2, 1915. Chart with text	Free.
Serial numbers of Weather Bureau publications	Free.

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